PHILOSOPHICAL TRANSACTIONS.

I. *On the Distribution of the Different Arteries supplying the Human Brain.*

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[Plates 1–8.]

Contents.

THE present work was undertaken to ascertain the area of distribution of the different arteries of the brain, when they were injected simultaneously under the same pressure with gelatine containing soluble colours, in place of the usual method of injecting the arteries singly and successively with insoluble colours held in suspension.

The work is illustrated by photographs of the different sections of the brains, reproduced in colours by the chromo-collotype process.

The number of brains which have been injected is 87.

Anatomy.

It is not proposed to give minute descriptions of the course and relations of the arteries and all their branches, but an enumeration is advisable of the arteries which will be considered.

The cerebral blood supply comes from the internal carotid and from the basilar arteries.

The *internal carotid* artery gives off the posterior communicating artery and the anterior choroid artery, and after giving off these branches it divides into the anterior and middle cerebral arteries.

The *posterior communicating* artery joins the posterior cerebral artery of the basilar.

The *anterior choroid* artery passes along and outside the optic tract to the anterior end of the inferior cornu of the lateral ventricle, which it enters, and there joins the choroid plexus.

The *anterior cerebral* artery courses in front of the corpus callosum and along its upper surface, and ends in the quadrate lobule.

The *middle cerebral* artery winds outwards along the Sylvian fissure to the cortex on the outer surface of the hemisphere, and there divides into four branches.

The *basilar* artery, which is formed by the union of the vertebrals of either side, divides at the upper border of the pons into the two *posterior cerebrals*, each of which turns outwards round the outer surface of the crus cerebri, and runs along the median surface of the occipital lobe to end in the posterior extremity of the calcarine fissure. Soon after its origin it is joined by the posterior communicating artery, a branch from the internal carotid.

Previous Observers.

It will not be necessary to mention all the writers on the subject, from HALLER and WILLIS down to ECKER, and I will therefore refer to those who have most recently added to our knowledge.

DURET* was the first to publish diagrams describing the different distributions of

* 'Archives de Physiologie,' 1874.

the anterior, middle, and posterior cerebral arteries. He did not describe the methods he used, and he did not state whether he employed a syringe, but he mentioned using injections of gelatine coloured by carmine, or by Prussian blue. He also did not state on how many different brains his observations were founded.

DURET divided the arterial circulation of the brain into—

1. Arteries of the base of the brain or of the cerebral nuclei.
2. Arteries of the ventricles.
3. Arteries of the cortical region or of the convolutions.
4. Arteries to second cephalic vesicle, cerebral peduncles, and corpora quadrigemina.
5. Arteries to fourth cephalic vesicle.

HEUBNER* was the first to investigate methodically the distribution of the different branches of the cerebral arteries. For this purpose he performed 60 injections on 30 brains, and used the method of injecting a single artery piece by piece, and noting the part of the brain that each piece supplied.

He used a solution of BRÜCKE'S Berlin blue, which was driven in very gradually, and with slight pressure, by a syringe.

He was the first to describe that the ramus communicans posterior supplied the anterior tubercle of the optic thalamus, and that the choroid artery supplied the posterior limb of the internal capsule, and the outer half of the anterior part of the thalamus. In his researches, the anterior choroid was injected alone in two cases, and the posterior communicating artery in four cases; in the remainder of his cases, the anterior, middle, or the posterior cerebral artery was injected.

HEUBNER divided the arterial system of the hemispheres into basal region and cortical region. In the former he considers that the vessels have no anastomoses, but are true end-arteries in the sense used by COHNHEIM. So that, "from a definite piece of an artery, a definite piece of brain substance is injected, and no more can be injected by increasing the pressure."

KOLISKO† made a special study of the supply of the anterior choroid artery, and repeated HEUBNER'S experiments, to ascertain "whether the posterior limb of the capsula interna is supplied by an artery, which has found no recognition in the scheme (of CHARCOT usually received), and which is not recognised as an end-artery."

He found that his experiments all gave the same result, and established HEUBNER'S assertion with reference to the posterior limb of the internal capsule. KOLISKO injected single arteries, using first TEICHMANN'S mass with finest chrome yellow or

* 'Centralbl. für die medic. Wissensch.,' 1872, No. 52; 'Die Luetische Erkrankung der Hirnarterien,' Leipzig, 1874.

† 'Ueber die Beziehung der Arteria Choroidea Anterior zum hinteren Schenkel der inneren Kapsel des Gehirnes,' Wien, 1891.

Berlin blue, which was injected by a syringe into the carotid artery after tying all branches except the anterior choroid. He obtained the best results with KADYI'S carmine olive-oil mass, which injected the finest capillaries, as well as the large vessels. A cobalt blue mass was used as a contrast, and also asphalt-lack-celloidin. He employed altogether 17 brains, of which the anterior choroid artery was alone injected in 10 brains, and in conjunction with the posterior communicating artery in six brains, and in four of these with injection of the middle cerebral also. In one case the posterior cerebral was alone injected.

It will be advisable to take the principal parts of the brain, and to compare the blood supply as it has been described by DURET, HEUBNER, and KOLISKO.

As there is not much difference of opinion about the cortical distribution, I will take first the supply to the basal ganglia and to the capsula interna.

The head of the *Nucleus caudatus* is supplied, according to DURET,* by the anterior cerebral artery which gives arteries "to the intraventricular nucleus of the corpus striatum. These arteries are not constant, as the ventricular nucleus may receive arterial blood from the ventricular arteries, and even by the Sylvian arteries." Further on (p. 86) he states that "the two main branches of the arteries of the choroid membrane end in the head of the corpus striatum. . . . Two or three times we have found small anastomoses of these branches with the arteries of the anterior perforated space. We have no doubt that, in certain cases, the ventricular nucleus of the corpus striatum is nearly exclusively supplied by the ventricular arteries."

According to HEUBNER,† it is the "part of the anterior cerebral artery between the arteria fossæ Sylvii and the ramus communicans anterior which gives off vessels which supply the head of the corpus striatum." The tail (surcingle) of the nucleus caudatus, according to DURET (p. 77),* is supplied by the lenticulo-striate arteries of the middle cerebral, and, according to HEUBNER (p. 179),‡ by a branch coming off from the first $2\frac{1}{2}$ cm. of the middle cerebral artery, by one of the middle cerebral arteries near the insula, and by the posterior communicating artery (p. 184), whereas, according to KOLISKO (p. 30),§ it is supplied by the ventricular branches of the anterior choroid artery (internal carotid).

The three divisions of the *Nucleus lenticularis* are considered to be supplied thus: the first and second divisions by the small internal lenticular branches of the middle cerebral (DURET, p. 77),* which probably correspond to the branches from the fork formed between the anterior and middle cerebral arteries, the supply described by HEUBNER (p. 819),† while, according to KOLISKO (p. 30),§ the first division is supplied by the anterior choroid artery. The third, or outer division, is supplied by the

* 'Archiv de Physiologie,' 1874, p. 70.

† 'Centralbl. f. die Med. Wiss.,' 1872, No. 52, p. 819.

‡ 'Die Luetische Erkrankung der Hirnarterien.'

§ *Loc. cit.*

lenticulo-striate and lenticulo-optic branches of the middle cerebral artery (DURET, p. 77),* which, according to HEUBNER (p. 810),† come off from the first 2 cm. of this artery. According to KOLISKO‡ (one observation, p. 19), the anterior half of the third division is supplied by the anterior cerebral.

The Thalamus Opticus.—DURET (p. 71)* states that the anterior internal part is supplied by the posterior communicating artery—a branch penetrating between the tuber cinereum and the corpora mammillaria, called the internal anterior optic; the internal posterior part is supplied by the branch from the posterior cerebral or posterior communicating artery, called internal posterior optic (p. 72); the external posterior part is supplied by the external posterior optic from the posterior cerebral artery, which enters the thalamus between the corpora geniculata (p. 82). Besides these basal branches, DURET considered that, from the choroid membrane, which gets its blood supply through the posterior lateral choroid branch from the posterior cerebral artery, "crowds of branches are detached which penetrate the thalamus," as ventricular branches (p. 86). In addition, the lenticulo-optic arteries of the middle cerebral artery are said to "end in the thalamus" (p. 77), but what part they supply is not stated.

HEUBNER (p. 820)† mentions that injection of the posterior communicating artery supplies the anterior inner part of the optic thalamus with a branch, which would correspond to DURET'S internal anterior optic artery, while the anterior outer part is supplied by the anterior choroid artery (p. 820), but whether the branches are basal, or are ventricular through the choroid plexus or membrane, is not clear; the posterior cerebral supplies the posterior half of the thalamus (p. 820).

KOLISKO (p. 32)‡ states that the posterior communicating artery supplies the anterior outer part of the thalamus—thus differing from DURET and HEUBNER, who made this artery supply the anterior internal part of this structure—and that, exceptionally, the anterior choroid supplies the outer part of the superior half of the thalamus (p. 30).

The Capsula Interna.—The supply of this part is not definitely described by DURET, but it is inferred (p. 79)* that it is supplied by the lenticulo-striate and lenticulo-optic branches of the middle cerebral artery. HEUBNER (p. 819)† was the first to describe that from the angle of the fork between the anterior and middle cerebral arteries, and especially from the former, the anterior limb or division of the capsula interna was supplied, an observation which has been in one experiment only confirmed by KOLISKO (p. 19).‡

With regard to the posterior division of the capsula interna, HEUBNER (p. 820)† first described that "from the arteria choroidea would be supplied the gyrus uncinatus, the neighbourhood of the cornu inferior of the lateral ventricle, the plexus choroideus of the cornu inferior, the posterior limb of the internal capsule."

* *Loc. cit.* † 'Centralbl. f. die Med. Wiss.,' 1872, No. 52. ‡ *Loc. cit.*

KOLISKO (p. 32)* finds that "the posterior division of the capsula interna was supplied by three arteries, the anterior choroid, the middle cerebral, the ramus communicans posterior."

He states that above the horizontal level of the superior angle of the middle segment of the nucleus lenticularis, the posterior division of the capsule is supplied by the middle cerebral, probably through the lenticulo-optic arteries of DURET, and that below this level "it is only the anterior one-third of the posterior division of the internal capsule which gets its blood supply from the posterior communicating artery. The posterior two-thirds of the posterior limb of the capsula interna is supplied by the anterior choroid artery, and with a very slender posterior communicating branch also the anterior one-third is supplied" (p. 33).

With regard to the branches which come from the trunk of the anterior choroid artery and supply the capsula interna, KOLISKO,* in one place (p. 31) states that they are end-arteries, and further on (p. 33) he described that "at the border between the deeper parts of the posterior division of the internal capsule, which are supplied by the anterior choroid and posterior communicating arteries, and the higher parts, which are injected from the arteria fossæ Sylvii (middle cerebral), the capillaries of the three arteries are in connection with each other. So that through these capillary anastomoses the region there of the three arteries merge into each other." It is therefore difficult to know whether he considered them to be end-arteries or not.

KOLISKO thinks "that the same condition existed between the region supplied by the arteria choroidea and the profunda, so that the branches of the latter can send by its offshoots to the thalamus (*artères optiques externes et postérieures* of DURET) blood to the capsula interna, and particularly to the lamina medullaris externa of the thalamus by means of capillary anastomoses" (p. 33). He also considered that the medullated white substance behind the capsula interna as far back as the roof of the descending cornu of the ventriculus lateralis was supplied by the ventricular branches of the anterior choroid (p. 30).

Choroid Plexus and Membrane.—The three observers mentioned above differ in their accounts as to the distribution of the choroid arteries.

The anterior choroid artery in its course to the cornu descendens of the ventriculus lateralis is considered by all the three authors to give branches to the tractus opticus, the crus cerebri and to the gyrus uncinatus, where, according to HEUBNER (p. 184)† and KOLISKO (p. 10),* it anastomoses with the branches of the posterior and middle cerebral arteries to this convolution. HEUBNER also described (p. 185) a distinct, "rather wide communicating branch between both arteries (the anterior choroid and posterior cerebral) which runs across the under surface of the crus cerebri"; whereas KOLISKO stated that this branch is sometimes, but not often,

* *Loc. cit.*

† 'Die Luetische Erkrankung der Hirnarterien.'

present (p. 12). According to HEUBNER (p. 184, *ut supra*) the anterior choroid supplied "a few vessels in the lateral part of the plexus choroideus"; according to DURET (p. 85),* after entering the cornu descendens, the anterior choroid artery "ends in the anterior extremity of the choroidal plexus . . . and traverses two-thirds of the extent of the plexus and gives fine branches to it." KOLISKO† stated (p. 11) that "the artery breaks up into numerous parallel branches in the plexus, from which one courses along the inner border of the plexus as far as the foramen Monroi, forming the continuation of the anterior choroid artery." "From the inner border of the plexus, and especially from the larger branch, the continuation of the anterior choroid, numerous branches go off and sink into the groove between the thalamus and the cauda of the corpus striatum." "The anterior choroid artery which goes to foramen Monroi as the artery of the inner border of the plexus gives off into the tela choroidea many branches, which anastomose with the branches of the arteria choroidea media, which enters the lateral transverse fissure from the profunda" (posterior cerebral) (p. 11). According to DURET,* however, "it is the posterior *lateral* choroid artery which completes the vascular supply of the choroid plexus; it gives branches to its anterior and superior third, the part above the optic thalamus. It comes from the posterior cerebral artery, and divides into an external branch to the choroid plexus and an internal for the choroid membrane" (pp. 85–86). "These two branches are separated at their entrance into the ventricle and their distribution is distinct." "The arteries of the choroid plexus take no part, in most instances, in the nutrition of the ventricular walls (p. 87), but send branches into the plexus which forms festoons or tufts." So that, according to DURET, the anterior choroid artery supplies the posterior two-thirds of the plexus, and, according to KOLISKO, it extends the whole way to the foramen Monroi. DURET makes the arteries of the choroid *membrane* supply vessels to the optic thalamus and end in the head of the corpus striatum and supply this freely and anastomose with the arteries of the anterior perforated space (p. 86). KOLISKO† thinks that from the inner border of the choroid plexus branches go off and sink into the groove between the optic thalamus and the tail of the caudate (p. 11). The posterior median choroid artery, according to DURET (p. 86),* "comes from the posterior cerebral artery when it is nearest the middle line, and it is directed forwards alongside the pineal gland and divides into two branches; one internal, for the choroid membrane of the third ventricle, the other external, terminating in the choroid plexus of this ventricle."

According to OBERSTEINER (p. 96)‡ "the plexus choroideus lateralis, with a vein, passes out of the lateral ventricle into the third ventricle through the foramen of MONRO and bends backwards in the plexus choroideus medius, which is on the under side of the tela choroidea near the middle line."

* *Loc. cit.* † *Loc. cit.*

‡ 'Anleitung der Nervösen Central-Organe,' 2nd edition, 1892.

With regard to other parts of the interior of the brain, DURET (p. 71)* and HEUBNER† pointed out that the posterior communicating artery supplies the commissura mollis, the corpus mammillare, the infundibulum, the ascending and posterior pillars of the fornix, the crus cerebri (tegmentum), and, according to HEUBNER, the tail of the caudate nucleus, while the inferior parts of the crus cerebri and the locus niger were supplied by the posterior cerebral.

In the cortical supply, according to DURET (p. 325, *et seq.*),* the area supplied by the anterior cerebral extends on the outer surface as far back as the fissure of Rolando, and outwards to the inferior frontal sulcus; and on the median surface it supplies the whole marginal gyrus, the gyrus fornicatus and the quadrate lobule, as far back as the internal parieto-occipital fissure. The area supplied by the posterior cerebral on the outer surface is bounded superiorly by a line drawn from the external parieto-occipital fissure forwards and downwards, just below and parallel to the parallel sulcus, and thence to the anterior end of the temporal lobe, so that the lower half of the second temporal gyrus is supplied by the posterior cerebral artery. On the median surface the posterior cerebral supplies all the area not supplied by the anterior cerebral, except the anterior quarter of the hippocampal lobule, which is supplied by the middle cerebral. On the outer surface the rest of the cortex, which is not supplied by the anterior or the posterior cerebral arteries, is supplied by the middle cerebral artery.

According to DURET (p. 78), there are no anastomoses between the different arteries penetrating the basal ganglia and no anastomosis between the cortical and basal arteries, as they are end-arteries, also no anastomotic network in the pia mater of the cortex (p. 318) or between the arterial twigs or between the arteries and veins (p. 340). He thinks, however, that there is an anastomosis (p. 319) between the three systems (anterior, middle, and posterior cerebral) at the confines of their borders, but that they cannot be very important, although he states that the whole cortex can be injected from one system.

DURET states (p. 334) that the medullary arteries of the cortex supply the white substance and the whole centrum ovale.

With reference to the cortical distributions of the arteries, I should mention that in CUNNINGHAM'S 'Text-book of Anatomy,'‡ the cortical circulation is illustrated by figs. 625, 626, where the area supplied by the anterior cerebral artery on the outer surface comprises the anterior portions of the superior and middle frontal convolutions, more posteriorly the upper portions of the superior and ascending frontal convolutions, and the upper parts of the ascending parietal and superior parietal convolutions. In the figures the anterior cerebral arterial area extends posteriorly on the external surface to the parieto-occipital fissure, where it joins the posterior cerebral area. Also in the figure of the distribution of the middle cerebral artery on

* *Loc. cit.*

† 'Die Luetische Erkrankung, etc., p. 184.

‡ 'Text-book of Anatomy,' edited by D. J. CUNNINGHAM, F.R.S., 2nd edition.

the outer surface, its parieto-temporal branch is made to extend posteriorly to midway between the posterior end of the parallel sulcus and the intra-parietal sulcus. Inferiorly the middle cerebral supplies the superior and middle temporal convolutions. Professor ARTHUR ROBINSON, who wrote the chapter on the cerebral circulation, has been good enough to inform me that the above figures were constructed from a series of 12 brains which were hardened *in situ* by formol and injected *in situ* by a paint-injection from the femoral artery with high pressure.

In TESTUT'S Anatomy,* in a diagram (fig. 807) of the arterial distribution on the outer surface of the cortex, the arrangement is very similar to that given by Professor ROBINSON, but I have not been able to ascertain how the diagrams in TESTUT'S work were made.

Method of Investigation.

In my earliest observations a brass syringe was used, with a screw-piston rod to regulate the pressure, and the three principal arteries were successively injected with Kadyi's† linseed oil mass containing carmine or Prussian blue. This method was found to be unsatisfactory, first from the circumstance that, there being communications between the areas of the cortex supplied by the different arteries, the area supplied by the artery injected first was liable to be invaded by the injection mass of the arteries subsequently injected, and thus a false result would be obtained; secondly, from the difficulty of penetrating the smaller vessels and capillaries with this injection mass, so that the larger vessels and not the areas supplied by them were injected.

The only way to obviate the first objection was to make the injections of all the arteries simultaneously by means of pressure bottles. For this purpose two large 20-oz. pressure bottles (aspirators) were used. They were joined at their lower openings by a rubber tube 8 feet long. Connected with the upper opening of one of these bottles by means of a three-way tube were the upper openings of three, four, or in some cases five smaller 4-oz. pressure bottles which contained the injection mass. These were connected at their lower openings by small indiarubber tubes with fine glass cannulæ, which were inserted and tied into the arteries. The pressure was thus gradually applied by raising the other large pressure bottle, which was not connected with the three-way tube, so that the height of the column of water between the two large pressure bottles, at the end of the experiment, was usually found to be 3 to 4 feet, while in some cases it was as high as 6 to 8 feet.

The injection mass used was warm liquid gelatine.

In the earliest injections I used the gelatine with Ranvier's carmine and Prussian blue according to BEALE'S formula, and also india ink, sepia, vermilion, and chromate of lead, but I failed to make these colours penetrate. After injecting

* 'Traité d'Anatomie Humaine,' par L. TESTUT, 2nd edition, 1893, vol. 2, p. 583.

† 'Ueber die Blutgefässe des menschlichen Rückenmarkes,' 1889.

12 brains with these colours with indifferent results, I found that after injecting with gelatine coloured with *soluble* carmine the colour remained fixed and did not come out in the hardening fluid (formalin), and the injection penetrated to the finest capillaries. Other soluble colours were then tried, and for the last 60 brains I have used soluble colours only.

The formula which I now use for the carmine mass is :—

Carmine, $\frac{1}{2}$ drachm [2 grammes]; ammonia, $\frac{1}{2}$ fluid drachm [1·8 c.c.]; glycerine, $\frac{1}{2}$ fluid oz. [14 c.c.].

Mix and add to gelatine, 2 ozs. [56 grammes]; water to 1 pint [568 c.c.].

The gelatine is soaked in cold water for half an hour, then melted in a water bath and the solution of carmine in ammonia and glycerine is added to it; water is added to make up to one pint, and the mass is filtered through flannel.

For the blue mass I use Nicholson's blue, prepared as follows :—

Nicholson's blue, 15 grains [1 gramme]; alcohol (90 per cent.), $\frac{1}{2}$ fluid oz. [14 c.c.].

Dissolve the blue in the alcohol and add to the gelatine mass as for carmine, making up to one pint with water.

With the brown and yellow colours great difficulties have been experienced. Bismarck brown has been used, but if any of it escapes it is liable to stain the cortex and it is not a good contrast to the carmine. It has been used in varying strengths as follows :—

Bismarck brown, 1–4 drachms [4–16 grammes]; methylated spirit, 3 fluid ozs. [85 c.c.]; glycerine, 1 fluid oz. [28 c.c.].

Dissolve and add to the gelatine mass as for carmine, making up to 1 pint [568 c.c.] with water.

Aniline blue black (nigrosine) was also used once, but it did not penetrate well.

For the yellow colour I have used gelatine coloured with saffron, aurantia yellow, primuline, orange amatto, madder, naphthol yellow, picric acid, pyoktanin yellow and others, but the colour has washed out in the formalin. Why some colours, as naphthol green, remain permanent (2–3 years), and others, as naphthol yellow, dissolve out in the formaline solution, is a chemical question which it is difficult to solve, but there is probably some combination between the gelatine, coloured with carmine or Nicholson's blue, and the formalin. The only yellow colours which were found so far to be stable were acridin yellow and orange yellow, which, though they wash out to a certain extent, were still visible in many cases a year after the injection.

The formula for acridin yellow is :—

Acridin yellow, 2 drachms [8 grammes]. Glycerine, 1 fluid oz. [28 c.c.].

Dissolve and add to the gelatine mass as for carmine, and make up with water to 1 pint [568 c.c.].

Gamboge and turmeric were tried, but they failed to penetrate further than the large arteries, and were of no use.

Of the green colours, naphthol green has proved to be a firm colour which does not wash out; it is used in the proportion of

Naphthol green, ½ drachm [2 grammes]. Glycerine, 2 fluid drachms [7 c.c.].

Rub into a smooth paste, and add a hot solution of gelatine (of strength of 2 ozs. to 1 pint) sufficient to make 1 pint as before.

The red, blue, and green are quite stable colours, and do not colour the hardening fluid at all; the yellow has caused the most difficulty, not only from its liability to wash out, but also from the fact that yellow most resembles the natural colour of the uninjected cerebral substance.

With regard to the question of the fixation of the colours, I have found that if the solid gelatine mass, coloured with carmine, Nicholson's blue, or naphthol green, be put into cold water, the colour is dissolved out; but after this gelatine has been put into the formaline mixture used for the hardening, the colours become fixed and do not wash out in water. In the case of gelatine coloured by yellow and brown, it was found that if alum be added in the proportion of 2 ozs. of a saturated solution of alum to a pint of the formaline solution (*i.e.*, 1 to 10), these colours are more permanent.

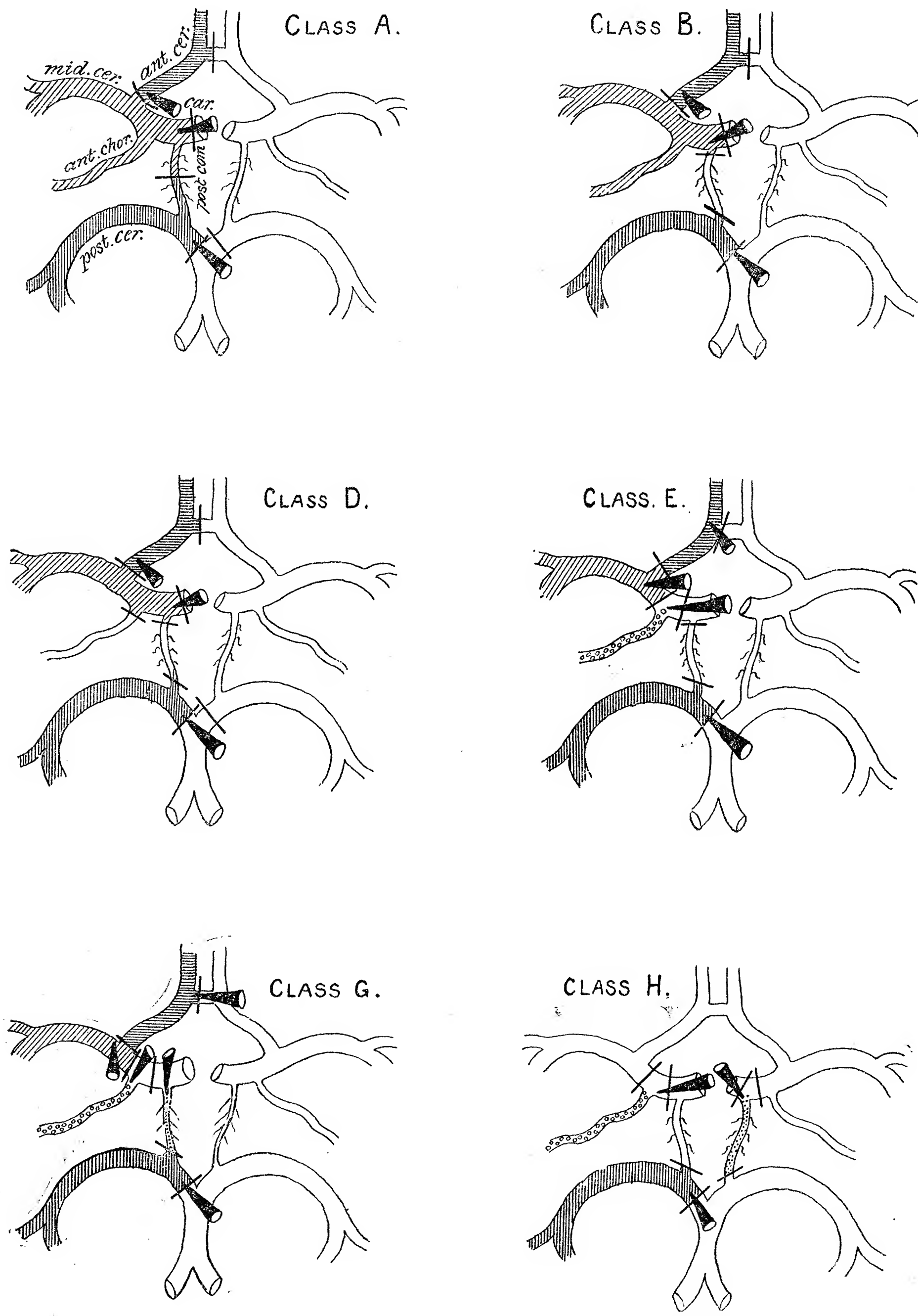
In making an injection, the smaller pressure bottles in connection with the arteries of the brain and the brain itself were immersed in a large basin of water at 40°–50° C., and the brain was first injected by means of the pressure bottles with water at about 50° C. to wash out the blood and to warm the interior of the brain. The melted coloured gelatine masses were then filtered through muslin into the injection bottles, and very gradual pressure was made by raising one of the larger pressure bottles till about 2 ozs. of each injection mass had been used. The pressure was then taken off by lowering the large pressure bottle and each of the indiarubber tubes leading to the cannulæ was clamped. If the pressure be kept up, and one of the small pressure bottles—say the anterior cerebral—be opened without the cannula tube being clamped, the injection in the area supplied by the middle cerebral artery may be driven into the area of the anterior cerebral artery and out of the anterior cerebral artery itself into its small pressure bottle. The tubes then being clamped were detached from the small pressure bottles, and the brain, without being handled, was put into cold water to fix the gelatine, and the trunks of the arteries were then ligatured off. The brain in every case has been hardened for a month or longer in a solution of formalin: formaldehyde 1 pint [568 c.c.], potassic nitrate 2 ozs. [56 grammes], potassic acetate 1 oz. [28 grammes], water 4 pints [2272 c.c.], to every pint of which 2 fluid ozs. [56·8 c.c.] of a saturated solution of alum had been added, which helps to fix the colours. After hardening, the brain has been cut by hand into sections in the horizontal, sagittal, or coronal plane, and preserved afterwards either in a weak formaline solution, or in a solution of glycerine (1 pint) [568 c.c.] and water (5 pints) [2840 c.c.], containing acetate of potash (2½ lbs.) [1134 grammes].

In the earlier experiments with the soluble colours, the anterior cerebral, the carotid, and the posterior cerebral arteries on one side were injected with three different colours after ligaturing the following arteries : The anterior communicating artery, the anterior cerebral artery close to its origin from the carotid, the posterior communicating artery, either midway or near the carotid and the posterior cerebral arteries, and the posterior cerebral artery of the other side (see diagrams, Classes A and B). In the next series of experiments, in order to make a differentiation between the areas supplied by the middle cerebral, by the anterior choroid, and by the posterior communicating arteries, the anterior choroid was ligatured close to the carotid and the posterior communicating was ligatured at both ends, near the carotid and near the posterior cerebral artery (Class D). The objection was found, however, in many cases that the area, which in special injections (*vide infra*) had been found to be supplied by the anterior choroid artery, was now injected by the injection mass from the posterior cerebral artery, thus showing that there was a free anastomosis, probably through the choroid plexus or on the temporal lobe, between these two arteries. This objection does not apply to ligaturing the posterior communicating artery, for, as its branches are end-arteries, they do not anastomose with other arteries and would not be injected by them.

Later, I have injected with four different colours—green, yellow, red, and blue—the areas supplied by the anterior cerebral, the anterior choroid, the middle cerebral, and the posterior cerebral arteries respectively, without the posterior communicating artery (Class E). Taking, let us say, the left hemisphere, the left anterior cerebral artery was injected by a cannula passed through the anterior communicating artery ; the left anterior choroid, by a cannula passed into the carotid close to the branching off of the anterior choroid, the carotid between the anterior choroid and the anterior cerebral arteries being ligatured ; the left middle cerebral was injected by a cannula passed into it from the anterior cerebral, which artery was ligatured immediately distally to the cannula ; and the left posterior cerebral artery was injected by a cannula passed into it from the basilar artery with ligation of the right posterior cerebral artery. The left posterior communicating artery was cut out by ligaturing it at either end.

An endeavour was made in several cases to ascertain the course of the blood flow in the posterior communicating artery before it was ligatured, by allowing water to flow through it under simultaneous pressure from the carotid and from the posterior cerebral arteries. It was found that on stopping the flow from the carotid by compressing the indiarubber tubing from its pressure bottle, the water flowed from the posterior cerebral to the carotid, but on relaxing the pressure on the carotid tube the direction was reversed and the water flowed from the carotid to the posterior cerebral artery, which is evidently the natural direction of the flow. The posterior communicating artery is considered by anatomists to be a branch of the carotid artery, but I can find no evidence that the direction of the blood from the carotid to the posterior

cerebral under conditions, which reproduce the normal circulation, has ever been shown experimentally.



Diagrams of the arteries forming the circle of WILLIS at the base of the brain, to explain where they were ligatured and injected in the classes A, B, D, E, G, H of the experiments. The cannulæ show where the injections were made, and the straight lines across the arteries where they were ligatured. The injection into the anterior cerebral artery (ant. cer.) is shown by horizontal shading, into the carotid (car.) or middle cerebral artery (mid. cer.) by oblique shading, into the posterior cerebral (post. cer.) by vertical shading, into the posterior communicating artery (post. com.) by dots, and into the anterior choroid artery (ant. chor.) by rings, where the last two are separately injected.

During the past year (1906), I have succeeded in injecting simultaneously five arteries on the same side, viz., the anterior, middle, and posterior cerebrals, the anterior choroid and the posterior communicating arteries with naphthol green, carmine, Nicholson's blue, acridin yellow, and Bismarck brown, respectively (Class G). The anterior cerebral artery was injected from a cannula passed through the anterior communicating artery, ligaturing the anterior cerebral close to the carotid; the posterior communicating artery from a fine cannula inserted into it from the carotid; the anterior choroid from a cannula tied into the carotid just beyond the posterior communicating artery, ligaturing the carotid on the distal side of the anterior choroid; the middle cerebral artery was injected from a cannula passed into it from the last piece of the internal carotid; while the posterior cerebral was injected from a cannula passed into it from the basilar artery, the posterior communicating artery being ligatured close to the posterior cerebral artery. Owing to the short space between the origin of the posterior communicating artery and the bifurcation of the carotid into the anterior and middle cerebrals, great difficulty was experienced in finding room for the three cannulæ, and it was impossible in some brains.

Besides the injections just described, in another set of experiments the posterior communicating and the anterior choroid arteries of opposite sides were simultaneously injected together with either the posterior or the middle cerebral artery (Class H).

In other cases the basal branches of the anterior cerebral, carotid, and posterior cerebral, arteries were injected without the cortical branches, by ligaturing these arteries just beyond where the basal branches were given off, and in other cases the cortical arteries alone were injected beyond the basal branches.

The experiments may therefore be divided into the following classes:—

Class A.—Where three colours were used to inject simultaneously the Anterior, Middle, and Posterior cerebral arteries of one side, ligaturing the Posterior communicating artery at one place. . . 36

Class B.—Where three colours were used for the same arteries, but the Posterior communicating artery was ligatured at both ends . . 7

Class C.—Where three colours were injected as above, but the Anterior choroid artery was ligatured near its origin, and the Posterior communicating near the Posterior cerebral artery 1

Class D.—Where three colours were injected as above, but the Posterior communicating artery was ligatured at either end, and the Anterior choroid artery at its origin 8

Class E.—Where four colours were used to inject simultaneously the Anterior, Middle, and Posterior cerebrals, and the Anterior choroid artery of one side, with cutting out by double ligature of the Posterior communicating artery 15

Class F.—Where four colours were used to inject simultaneously the Middle and Posterior cerebrals, the Posterior communicating, and either the Anterior cerebral or Anterior choroid, on the same side . .	2
Class G.—Where five colours were used to inject simultaneously the Anterior, Middle, and Posterior cerebral arteries, the Anterior choroid and the Posterior communicating arteries, all on the same side	2
Class H.—Where the Anterior choroid and the Posterior communicating arteries on opposite sides with the Posterior or Middle cerebral arteries were separately injected simultaneously, with three colours.	5
Class I.—Where only the basal or the cortical branches of the three chief arteries were separately injected	7
Class J.—Where the lateral ventricle was exposed, and the Anterior choroid and Posterior cerebral arteries were separately injected. . . .	2
Class K.—Where the Anterior and Middle cerebrals were separately injected with ligature of the Posterior cerebral near the cuneus.	1
Class L.—Where the Anterior, Middle, and Posterior cerebrals were injected separately after ligaturing the ascending parietal branch of the Middle cerebral artery	1
Total	87

Taking the above classes from A to G, the number of brains which were cut horizontally was 46, the number cut coronally was 17, those cut sagitally numbered seven. One brain in Class A was not cut and was used for photographing for the cortical distribution.

The brains were taken from subjects of both sexes, the ages ranging from 7 months to 77 years, and it was particularly observed that the cases, where the injection did not penetrate well, were those suffering from granular nephritis or alcoholism, where there was much fluid in the subarachnoid space of the brain.

It has been objected to soluble colours that it would not be possible to use them, as they would at once transude through the capillaries into the tissues, and so give false results. An examination of a brain injected with gelatine and soluble colour shows an absolutely hard and fast line between the areas supplied by two different colours, and under the microscope the fine vessels can be seen to be injected without staining the surrounding tissues. I would point out that the great advantage of using soluble colours is that the injection of the finest capillaries is accomplished, and the exact distribution of each artery can be seen, and not the probable distribution deduced from the injection of the larger trunks.

I submit that the method employed has given such exact results and a

differentiation so definite that it has been possible in coronal sections to show, in the case where five arteries were injected, that the Corpus subthalamicum (LUY's body) has sometimes a double supply, its superior external part being injected by the posterior communicating artery, while its internal inferior part is injected by the posterior cerebral artery (p. 55). The fact that so small a body as the corpus subthalamicum can receive its blood supply from two different arteries is against the theory that the arrangement of the blood supply can have any functional significance, as it appears to be purely anatomical and not distributed according to the physiological action of the part. Another instance of the same condition is the middle segment of the Lenticular nucleus, which is supplied in some brains by three separate arteries (pp. 22 and 23).

It will be advisable to take first the parts of the interior of the brain supplied by the different arteries—basal branches, and then the distribution on the external surface—the cortical branches.

The Basal Distribution.

As far as possible the parts supplied will be described in the order of the flow of the blood, *i.e.*, the crus cerebri will be described before the capsula interna.

Regio subthalamica and Pes pedunculi.—In describing the arterial supply to the Crusta or Pes pedunculi it will be advisable to take at the same time the Regio subthalamica; the region which lies below the thalamus and is bounded ventrally by the Lamina perforata posterior or the Corpus mammillare, medially by the third ventricle and the anterior pillar of the Fornix, externo-laterally by the internal capsule and the reticular zone of the thalamus, and posteriorly by the Nucleus Ruber, while anteriorly it is continuous with the Substantia innominata. The region is shown in horizontal and coronal sections (Plates 4 and 6, figs. 8 and 11).

I have observed the blood supply to this region in 21 cases. Taking the Regio subthalamica first, it was found that in eight cases this was supplied by the Posterior communicating artery and in eight cases, where this artery was cut out, this area was not injected and was presumably* supplied by this artery. In one case it was supplied by the Anterior cerebral, in one other by the Anterior choroid, and in one other by the Anterior choroid in the lower level and in the upper level by the Posterior communicating artery. In two cases the anterior third of the wall of the third ventricle was injected by the Anterior cerebral, while its posterior part was presumably supplied by the Posterior communicating artery.

The *Corpus mammillare* was noted in eight cases to be supplied by the Posterior cerebral and three times by the Posterior communicating artery.

The *Pes pedunculi* was, in five cases, entirely supplied by the Anterior choroid artery. In two cases the anterior third only was supplied by the Anterior choroid

* An area is considered to be "presumably" injected by an artery, when after ligation of an artery this area is not injected, but is injected when this particular artery is injected in other cases.

artery. In six cases the anterior third was not injected when the Posterior communicating artery was ligatured, and in six cases it was supplied by the Posterior communicating artery when this was separately injected. The posterior two-thirds of the Pes pedunculi was supplied in three cases by the Anterior choroid artery, and in 11 cases by the Posterior cerebral artery. This would give seven cases where the anterior one-third was supplied by the Anterior choroid, and 12 cases where it was supplied by the Posterior communicating artery; while in 8 cases the posterior two-thirds were supplied by the Anterior choroid and in 11 by the Posterior cerebral artery.

Out of seven cases the supply to the *Corpus subthalamicum* (LUY'S body) was noted to come in three cases from the Posterior communicating artery and in two cases it was not injected when this artery was alone cut out; in one case the external superior half was supplied by the Posterior communicating artery and the inferior half by the Posterior cerebral artery; and in one case by the Anterior choroid. The part known as *Forel's field* was in three cases supplied by the Posterior communicating artery. The *Nucleus Ruber* was in six cases seen to be supplied by the Posterior cerebral artery.

The *Internal capsule* has a different supply in the anterior and posterior segments, and also in the superior part as compared with that nearer the base.

The *Anterior segment* was supplied by the Anterior cerebral and by the Middle cerebral artery. In the 41 cases in which the distribution could be observed, the part of the capsule nearest to the base was supplied by the Anterior cerebral, while the part nearest to the vertex was supplied by the Middle cerebral. The amount supplied by the two arteries varied in different cases and agreed with the different degrees with which the caput of the nucleus caudatus was supplied by these two arteries. In the majority of cases (23 in number) the part of the anterior segment of the internal capsule, which is below the horizontal level of the middle of the head of the caudate nucleus, was definitely supplied by the anterior cerebral and the part above this level was supplied by the middle cerebral artery. In two other cases the superior five-sixths and one-quarter respectively were supplied by middle cerebral, and the inferior one-sixth and three-quarters by the anterior. In one case the whole of the anterior segment was supplied by the anterior cerebral; in two cases entirely by the middle cerebral artery; and in one case the anterior part was supplied by the anterior cerebral and a small posterior part opposite the middle segment of the lenticular nucleus was supplied by the middle cerebral. Of the remaining cases, seven were described as being supplied by the middle and five by the anterior cerebral arteries, but the degree of supply could not be ascertained owing to the injections not being complete.

The *Posterior segment* of the Capsula interna is supplied by three arteries, the Posterior communicating, the Anterior choroid, the Middle cerebral, and in some cases, to a slight degree, by the Posterior cerebral. Taking the supply of the Posterior communicating artery first, I have in 29 cases injected a hemisphere cutting out the area supplied by the Posterior communicating artery by ligaturing it at both

ends, and in eight of these cases (Class D, p. 14) the Anterior choroid artery was also ligatured at its origin at the same time. In five cases the Posterior communicating and Anterior choroid arteries were injected with different colours together with the Posterior or Middle cerebral arteries (Class H), and in four cases the Posterior communicating artery was injected with three or four other arteries (Classes F and G). In the 29 cases cited above, the anterior one-fourth or one-third of the posterior segment of the capsula interna was not injected in any, and in the nine cases where the (Classes F, G, H) Posterior communicating artery was separately injected, in six the anterior one-fifth or one-third of the posterior limb of the capsule was injected.

The remaining two-thirds of the posterior limb of the capsula interna are supplied by the Anterior choroid artery. Of seven cases in which the three chief arteries were injected with three colours, ligaturing the Anterior choroid and the Posterior communicating arteries (Class D), the posterior two-thirds of the posterior limb was not injected in one case, and in six it was injected by the Posterior cerebral artery. This last result was considered to be due to the free anastomosis existing between the Anterior choroid artery and the Posterior cerebral arteries (see pp. 6, 7, and 12), so that when the former was ligatured, its area was supplied through the Posterior cerebral artery. The Anterior choroid artery was injected separately in 22 cases, six being with separate injection of the Posterior communicating artery (Classes F and H), 14 being with separate injection of the three chief arteries and with cutting out of the posterior communicating (Class E), and two being with separate injection of the four other arteries (Class G). In 20 out of the above 22 cases, the posterior part of the posterior limb, varying from three-fourths to one-fifth of its length, was supplied by the Anterior choroid artery.

The Anterior choroid artery also supplied the white matter on the external surface of the thalamus, the zona reticularis.

I have made special observation of the blood supply of the *Genu* of the Capsula interna, and found in all cases that the anterior segment of the Internal capsule was supplied by the Anterior or Middle cerebral artery—according to the level—as far posteriorly as the internal angle of the Nucleus lenticularis. In some cases these arteries supplied the fibres from the anterior segment of the internal capsule, which can be seen on horizontal sections to pass into the anterior part of the optic thalamus, forming its anterior peduncle. The posterior segment of the Internal capsule at the genu was supplied by the Posterior communicating artery as far anteriorly as a line drawn across, in horizontal sections, from the inner angle of the Lenticular nucleus to the angle formed between the Optic thalamus and the Caudate nucleus.

It will thus be seen that the part of the anterior limb of the Internal capsule which forms the genu is supplied in most cases by the anterior cerebral artery, while the part of the posterior limb which contributes to form the genu is supplied by the posterior communicating artery. I would, therefore, wish to refer to a

paper* by Sir VICTOR HORSLEY and myself in which we showed in the monkey (*Macacus sinicus*) that electrical stimulation of the fibres in the anterior part of the genu at the most posterior part of the anterior segment of the internal capsule produced conjugate movements of the eyes to the opposite side. As this posterior part of the anterior segment has a different blood supply from the posterior segment, it is probable that this fact may explain how, in hemiplegia due to thrombosis of the posterior communicating and anterior choroid arteries supplying the posterior segment of the internal capsule, the fibres in the anterior segment, which on stimulation produce conjugate movement of the eyes to the opposite side, may escape, and the paralytic symptom of conjugate deviation of the eyes towards the side of lesion may be absent; whereas in cases of hemiplegia due to a large hæmorrhage from the middle cerebral artery, there is nothing to prevent the extravasation of blood from destroying the fibres of the anterior segment of the internal capsule, and so produce conjugate deviation of the eyes away from the paralysed side.

The Anterior choroid artery not only supplies the posterior two-thirds of the posterior segment of the internal capsule, but also the medullated white matter, which has been called the retro-lenticular fibres, extending posteriorly to the capsule as far back as opposite the splenium of the corpus callosum (Plates 3 and 7, figs. 6 and 14). This white matter forms the roof of the descending cornu of the lateral ventricle, extending to its anterior end, and in sagittal sections this area is found to extend from the roof of the descending cornu of the Lateral ventricle below to the Claustrum above, and posteriorly to the Sylvian fissure, where it forms the roof to the junction of the descending cornu with the main body of the ventricle. In coronal sections this area, supplied by the Anterior choroid, is seen to comprise all the white matter between the Optic thalamus and, but not including, the External capsule. It extends outwards into the white matter of the superior temporal convolution, and forwards to the part between the roof of the descending cornu of the Lateral ventricle and the Lenticular nucleus, where it includes also the fibres forming the medullary lamina between the middle and inner segments of the Nucleus lenticularis.

It will thus be seen that the Optic radiations where they emerge from the Optic thalamus must be supplied through their entire coronal dimension by the Anterior choroid artery. This distribution to the Retro-lenticular fibres of the Anterior choroid was found in all the five cases in which the Anterior choroid and Posterior communicating arteries were injected separately (Class H), and in 10 of the 16 cases where the Anterior choroid artery was injected separately with the other chief arteries (Classes E, F, G).

In coronal sections (Plate 6, figs. 11 and 12) it is seen that the supply to the internal capsule by the Anterior choroid artery extends up to a certain level, which was given by KOLISKO† as that of the upper angle of the middle segment of the

* 'Phil. Trans.,' B, 1890, p. 49.

† *Loc. cit.*, p. 32.

Lenticular nucleus, and that above this level the Internal capsule was supplied by the Middle cerebral artery. It is to be noted that the line separating the Anterior cerebral from the Middle cerebral arterial supply of the Corpus striatum and of the anterior segment of the capsule is arranged as a curve round a centre at the base of the brain, and is continuous with the line separating the Anterior choroid supply of the Internal capsule, posterior segment from the Middle cerebral supply, and also that in sagittal sections this line between the two areas (Plate 1, fig. 2) can be seen to slope backwards and upwards to about the vertical level of the coronal section through the most anterior part of the Pons, and to follow the outline of the Nucleus caudatus in its horizontal part. This arrangement was found in all the cases in which it could be ascertained.

In coronal sections the curved arrangement of the area of the middle cerebral supply is well seen and it follows the course of the lenticulo-striate and lenticulo-optic arteries of DURET, and it explains how the blood gets from the base of the brain to the caudate nucleus by the arteries which pass through the outer part of the lenticular nucleus, external to the distribution of the anterior cerebral, of the posterior communicating, and of the anterior choroid arteries.

In horizontal sections (Plate 2, fig. 4) it is seen that the external nucleus of the Optic thalamus (Th. n. e.) (see p. 25) is supplied by the Posterior cerebral artery, and it was found that in some cases the area of the Posterior cerebral artery extended on to the contiguous part of the posterior two-thirds of the posterior segment of the Internal capsule. In other cases the area of the Posterior cerebral artery extended across the Internal capsule in the form of a horn. This was particularly noticed opposite to the posterior end of the middle segment of the Lenticular nucleus.

In coronal sections at the posterior part of the superior level of the posterior segment of the Capsula interna a narrow band was seen, showing an arterial supply from the Posterior cerebral artery, which coursed across the Internal capsule from the tail of the caudate nucleus—which was here supplied by the Posterior cerebral artery —outwards and downwards to the inner superior angle of the outer segment of the Lenticular nucleus. Its first appearance corresponded to the posterior limit of the supply of the Middle cerebral artery to the superior part of the Internal capsule. Traced backwards, this Posterior cerebral artery supply expanded into the large area of white matter situated near the superior external posterior part of the Optic thalamus which is supplied by the Posterior cerebral artery.

In describing the arterial supply to the Posterior segment of the Internal capsule, I would say that I have never seen any anastomosis between the Posterior communicating, the Anterior choroid, and Middle cerebral arteries, as has been described by KOLISKO (see p. 6), and I look upon them as "end-arteries," for, when the Posterior communicating artery is ligatured at both ends, the part of the Internal capsule, which should be supplied by it, is not injected by the Middle cerebral or Anterior choroid artery, and when the Anterior choroid artery is ligatured, its area is supplied

not by the Middle cerebral artery, but by the Posterior cerebral artery, which injects the choroid plexus and thus reaches the Anterior choroid artery and the area supplied by it.

Nucleus caudatus.—In describing the arterial supply of the *Caudate nucleus*, it will be necessary to take its different parts separately. It reaches from the caput in front to where it arches over the Optic thalamus posteriorly and extends downwards between this and the Lenticular nucleus, to reach inferiorly the descending cornu of the Lateral ventricle to end in the anterior extremity of the temporal lobe in the Nucleus amygdalæ. As the Nucleus caudatus has a different blood supply in the different parts of its course, it will be advisable to describe the Caput or Head, the superior horizontal part, and the descending part, Surcingle, in the descending cornu of the lateral ventricle.

The arterial supply to the *Caput* or *Head of the Caudate nucleus* is very similar to that of the anterior part of the Lenticular nucleus, and is in favour of these two ganglia being included together under the term of Corpus striatum.

In 22 out of 39 observed cases the inferior half of the head was supplied by the Anterior cerebral artery, and the superior half was supplied by the Middle cerebral artery. The dividing line between the two areas was in most cases at right angles to the direction of the anterior limb of the Internal capsule, as seen in coronal sections, and divided the head into two equal parts.

In the remaining cases the degree in which the head was supplied by the two arteries varied from its being entirely supplied by the Anterior cerebral in eight cases to its being entirely supplied by the Middle cerebral in two cases; while in two other cases the Anterior cerebral supplied the anterior three-fourths of the head, and in four other cases the inferior three-fourths, one-third, one-fourth, and one-eighth respectively, the rest of the Caput being supplied by the Middle cerebral artery.

I have never seen the head of the Caudate nucleus supplied by the arteries to the choroid membrane from the Posterior cerebral artery as described by DURET* (see p. 7), and I have consequently never seen any anastomosis between the Posterior cerebral and the Anterior cerebral arteries in the Caudate nucleus.

The *superior horizontal part* of the *Caudate nucleus* seen in the lateral ventricle was supplied in all cases by the Middle cerebral artery (38 observations). In only one case was the anterior one-third supplied by the Anterior cerebral artery. The part supplied by the Middle cerebral extended posteriorly to the coronal section made just in front of the pons or through its anterior part (Plate 7, fig. 14).

The part of the Caudate nucleus—which now forms the *Tail* or *Surcingle*—which is behind this section is differently supplied. In all cases except two, where it could be observed, the Surcingle posterior to the part nourished by the Middle cerebral artery was supplied by the Posterior cerebral artery as far posteriorly as the upper end of the descending cornu of the Lateral ventricle. From this point forwards to the

* *Loc. cit.*, pp. 86, 87.

termination of the Surcingle in the Nucleus amygdalæ it was supplied by the Anterior choroid artery. In the two exceptions mentioned above, all the Surcingle posterior to the Middle cerebral distribution was supplied by the Anterior choroid, while in some of the other cases the Posterior cerebral supply extended for only $\frac{1}{4}$ inch.

Nucleus lenticularis.—The *External* or *third Segment* (Putamen) of the Lenticular nucleus is supplied mostly by the Middle cerebral artery in all the cases. In 32 out of 52 observed cases the anterior inferior part was supplied by the Anterior cerebral artery—the anterior superior part being supplied by the Middle cerebral artery,—and in nine cases by the Middle cerebral artery. Therefore in these last nine cases the Middle cerebral would supply the whole of this segment. On the other hand, the area supplied by the Anterior cerebral artery is sometimes much increased, so that in six cases the whole anterior half of this segment was supplied by this artery. In some of the cases where the Anterior choroid artery was separately injected it was found to inject the posterior and inferior part of this segment. The dividing line between the areas supplied by the Anterior and Middle cerebral arteries was in most cases through the middle of the anterior limb of the internal capsule, and at right angles to the direction of the capsule as seen in coronal sections. It was therefore continuous with the dividing line in the Caudate nucleus.

The *Middle or second segment* of the Nucleus lenticularis—which with the internal segment forms the Globus pallidus—holds a position in regard to its blood supply intermediate between the internal and the external segments, in that although it is supplied chiefly by the Anterior and Middle cerebral arteries, it is also in some cases supplied by the Anterior choroid artery.

In the earliest cases (Classes A and B) where the Anterior choroid was injected from the Internal carotid artery, in three cases the middle segment was entirely injected by the Anterior cerebral artery, while in five cases only the anterior inferior part was injected by this artery, so that it was doubtful here how much of the remaining part of the segment in the five cases was supplied by the Middle cerebral, and how much by the Anterior choroid.

Of eight cases when the Anterior choroid was ligatured and the Posterior communicating artery was also ligatured at both ends (Class D), the middle segment was supplied completely by the Middle cerebral artery in three cases; in one case the anterior half—and in another the anterior one-eighth—was supplied by the Anterior cerebral, while the posterior half and the posterior seven-eighths were supplied by the Middle cerebral artery. In one anomalous case the anterior inferior quarter was supplied by the Anterior cerebral artery, the anterior superior quarter by the Middle cerebral artery, and the posterior half was not injected and was presumably supplied by the Anterior choroid artery. In one case, where the Anterior choroid artery was alone ligatured, the anterior half was supplied by the Anterior cerebral and the posterior half was not injected and was presumably supplied by the Anterior choroid artery (Class C).

Of 14 cases where the Posterior communicating artery was cut out and the Anterior choroid was separately injected with the three other arteries (Class E) and of two in Class F (p. 15), in eight cases this segment was entirely supplied by the Middle cerebral artery, and in one entirely by the Anterior choroid artery; in one case the anterior part was supplied by the Anterior cerebral, the middle by the Middle cerebral, and the posterior part by the Anterior choroid arteries; in two cases the anterior part was supplied by the Anterior cerebral and the posterior part by the Middle cerebral; in two others this segment was partly supplied by the Middle cerebral and partly by the Anterior choroid artery; while in one the posterior part was supplied by the Anterior choroid, and the anterior part was not injected and was presumably supplied by the Posterior communicating artery, which was ligatured at either end and not injected.

In the two cases where the five arteries have been separately injected (Class G), in one the anterior inferior half was supplied by the Middle cerebral and the rest by the Anterior choroid artery, while in the other case the anterior inferior half was supplied by the Anterior cerebral and the rest by the Middle cerebral artery.

To sum up, the middle segment of the Nucleus lenticularis was in three cases entirely supplied by the Anterior cerebral artery; in 12 cases it was partly supplied by the Anterior cerebral artery in its anterior part. In 11 cases it was entirely supplied by the Middle cerebral artery and in 10 partially supplied by this artery, chiefly in its posterior part. In one case it was entirely supplied by the Anterior choroid artery, and in seven cases only in the posterior part. One was presumably partly supplied by the Posterior communicating, but it is evident that this supply is not the usual one, as in the five cases where the Anterior choroid and Posterior communicating arteries were separately injected the middle segment of the Lenticular was not supplied by these arteries in any case.

The most frequent supply, therefore, would be either entirely by the Middle cerebral artery, or with the anterior inferior part supplied by the Anterior cerebral artery; and less frequently with the posterior part supplied by the Anterior choroid artery.

The *Internal* or 1*st Segment* of the Nucleus lenticularis was entirely injected by the Internal carotid artery in all the cases (Class A) where the Anterior choroid and Posterior communicating arteries were not ligatured off from the Carotid (with the exception of two cases which were partly supplied by the Anterior cerebral, and one which was supplied by it entirely). Out of seven cases where the Posterior communicating artery was alone cut out and the Anterior choroid was injected from the Internal carotid (Class B), this segment was not injected in two cases in its anterior half and was presumably supplied by the Posterior communicating artery. Out of five cases (Class D) where the Posterior communicating was cut out and the Anterior choroid was ligatured, in three the internal segment was not injected and in two it was injected by the Posterior cerebral artery, which had invaded the anterior choroid area (see p. 12).

In 12 cases where the Anterior choroid was separately injected with the principal arteries and the Posterior communicating artery was cut out (Class E), the internal segment was injected in every case by the Anterior choroid artery. In one of these cases the posterior half only was injected by the Anterior choroid, and, as the anterior half was not injected, it was presumably supplied by the posterior communicating artery, which was the only one which was cut out.

In five cases where the Anterior choroid and Posterior communicating arteries were separately injected along with one other artery (Class H), this segment was supplied in all by the Anterior choroid; but of these, in one the posterior half only was supplied by this artery and the Anterior half by the Posterior communicating, whilst in one other example it was the outer half that was supplied by the Anterior choroid and the median part by the Posterior communicating. In the one case (Class C) where the Anterior choroid was ligatured off from the Carotid, but not the Posterior communicating, the anterior half of this segment was supplied by the Anterior cerebral artery, which in this particular brain had an unusually large distribution (including the whole of the head of the Caudate nucleus and a large part of the rest of the Lenticular nucleus), while the posterior half of this segment was not injected, and presumably had its supply from the Anterior choroid.

In one case (Class F) where the four arteries without the anterior cerebral were injected, this segment was injected entirely by the anterior choroid.

In the two cases where five arteries were injected (Class G), in one case the first segment was entirely injected by the Anterior choroid; while in the other this artery injected the posterior half and the Anterior cerebral supplied the anterior half.

To sum up, besides all the cases where the Internal segment was injected by the Internal carotid presumably through the unligatured Anterior choroid artery, in 20 cases out of 23 possible cases (Classes E, F, G, H) it was certainly supplied by the Anterior choroid, in 16 completely, in four for only the posterior or external half; in two it was partly supplied by the Posterior communicating artery and in three presumably so; while in four it was supplied by the Anterior cerebral artery, one entirely and three in the anterior half.

Optic thalamus.—The arterial supply of this ganglion comes chiefly from the Posterior cerebral artery, but it is nearly always supplied also by the Posterior communicating artery. The Optic thalamus is divided into the following nuclei, the anterior, the external, the internal, and the pulvinar, and it might be supposed that the different nuclei would each have a special blood supply, but with the exception of the anterior nucleus and the pulvinar, this does not seem to be the case. Only those examples were taken in which the Posterior communicating artery was either separately injected, eight cases (Classes F, G, H), or was cut out, 27 cases (Classes B, D, E), 35 altogether.

In 16 of these cases the *Anterior nucleus* was supplied by the Posterior cerebral

artery and the injected nucleus often stood out as an island in the rest of this part of the thalamus (Plate 6, fig. 11). In seven cases, where the Posterior communicating was the only artery ligatured, this nucleus was not injected and was presumably supplied by this artery, and in one case it was injected when this artery was separately injected. In the one case (Class C) where the Anterior choroid was alone ligatured, the anterior nucleus was not injected, and in one case it was not injected where both Posterior communicating and Anterior choroid were ligatured.

The *External nucleus* lying on the outer side of the anterior nucleus has a different supply in its various parts. Its most anterior superior part was in eight cases supplied by the Posterior cerebral artery, in two cases it was supplied by the Posterior communicating, and in three cases it was not injected, when this artery was the only one cut out. The anterior external part which receives the main part of the anterior peduncle from the anterior division of the internal capsule was supplied by the Posterior cerebral in three cases, by the Posterior communicating in four cases, and it was not injected in 11 cases where the Posterior communicating artery was alone cut out, and not injected in three cases where in addition the Anterior choroid was ligatured. Besides these, three cases were noted in which the anterior half of the Thalamus was not injected when the Posterior communicating artery was alone cut out, and in three others it was uninjected, when in addition the Anterior choroid was ligatured; also in one case the anterior half of the Thalamus was injected by the Posterior communicating artery. The posterior half of the external nucleus was supplied by the Posterior cerebral artery in all cases, with the exception of one case where the posterior superior part was injected by the Anterior choroid artery, and in another where a vertical figure-of-eight-shaped area in the middle of the external nucleus was not injected when the Posterior communicating was alone cut out. It seems probable that the superior external part of the Optic thalamus containing the posterior half of the external nucleus is the part supplied by the Posterior cerebral artery through the choroid membrane,—which here gives off numerous branches which sink into the Thalamus,—because, in one case (Class K) where the Posterior cerebral artery was ligatured in the calcarine fissure near the anterior apex of the cuneus, and only the Anterior and Middle cerebrals were injected, this nucleus was the only part of the Optic thalamus which was injected. It was injected with carmine from the Middle cerebral artery, presumably through the Anterior choroid artery, which had injected with carmine the whole of the choroid membrane and plexus.

The *Internal nucleus* was observed in 10 cases to be supplied entirely by the Posterior cerebral artery. In nine cases it was found to be supplied by this artery in the posterior half only; the anterior half in these cases was not injected and was presumably supplied by the Posterior communicating artery, which was the only one which was cut out. In one case where the Posterior communicating artery was separately injected, it supplied the anterior part of this nucleus. (Plates 6 and 7, figs. 11, 12, and 13.)

The posterior part of the Optic thalamus, including the *Pulvinar*, was in all cases supplied by the Posterior cerebral artery.

I have in no case, except the two (one presumably) mentioned above found any supply to the Optic thalamus from the Anterior choroid artery, and in no case has there been any supply from the Middle cerebral artery. Therefore the so-called lenticulo-optic arteries of DURET do not supply the Optic thalamus according to my observations.

To sum up. The Anterior nucleus was supplied by the Posterior cerebral artery in 16 cases, by the Posterior communicating in nine cases (eight presumably), and in one case presumably by the Anterior choroid artery. The External nucleus in its anterior superior part was in five cases (three presumably) supplied by the Posterior communicating, and in eight cases by the Posterior cerebral artery; in its anterior external part in 25 cases (20 presumably) by the Posterior communicating, and three by the Posterior cerebral; the posterior half of this nucleus was supplied by the Posterior cerebral in all, except in one case by the anterior choroid and in one presumably by the Posterior communicating. The Internal nucleus was in 19 cases supplied by the Posterior cerebral in its posterior half, and in 10 cases by this artery in its anterior half, while in one case this half was injected by the Posterior communicating artery and in nine cases presumably supplied by this artery. The posterior part, including the Pulvinar, was in all cases supplied by the Posterior cerebral artery.

Choroid plexus and membranes.—As was shown on p. 6, the accounts of the arterial supply of these parts given by DURET and KOLISKO differ very much. In my cases, where it could be satisfactorily observed, it was found that the supply of the plexus had a different distribution to that of the membrane. Taking first the plexus in the descending cornu of the lateral ventricle, it was found that in 13 cases the plexus was supplied by the Internal carotid artery, when the Anterior choroid artery was not ligatured; and in eight cases, out of 11, where it could be observed, it was supplied by the Anterior choroid artery, when this vessel was separately injected. The plexus was injected by these vessels as far back as the upper posterior end of the descending cornu, where it joins the central part of the Lateral ventricle. The globular expansion of the plexus in the posterior cornu of the ventricle was in rather more than half of the cases supplied by the Anterior choroid artery—the other cases being supplied by the Posterior cerebral.

In five cases the plexus was supplied by the Anterior choroid artery only as far posteriorly as the outer surface of the Crus cerebri, beyond which it was supplied by the Posterior choroid from the Posterior cerebral, and in two cases the supply of the Anterior choroid extended along the central part of the lateral ventricle as far as the highest point of the optic thalamus.

In all cases the supply of the Choroid plexus in the central part of the lateral ventricle was from the Posterior cerebral artery, either through the lateral posterior choroid or the median posterior choroid arteries, which latter enters the median

choroid plexus of the third ventricle near the middle line of the transverse fissure, and passes through the foramen of MONRO to be continuous with the lateral choroid plexus of the central part of the lateral ventricle.

The *Choroid membrane* was supplied almost entirely by the lateral Posterior choroid artery, which passes from the Posterior cerebral artery outwards into the descending cornu of the Lateral ventricle opposite the posterior surface of the Crus cerebri. The part of the membrane in the anterior part of the descending cornu, which is anterior to the entry of the lateral choroid artery, was observed in six cases, where the anterior choroid was not ligatured, to be supplied by the carotid, and in five cases by the anterior choroid when this artery was separately injected. In one case the Anterior choroid supplied the membrane in the whole of the descending cornu.

The part of the membrane in the descending cornu, posterior to the entrance of the lateral posterior choroid artery, and the part in the central lateral ventricle was, in all the other cases in which it could be observed, supplied by the Posterior cerebral presumably by its branch, the lateral posterior choroid artery.

To sum up. The Choroid plexus is usually supplied by the Anterior choroid artery in the descending cornu and in the posterior cornu, while in the central part of the Lateral ventricle it is supplied by the Posterior cerebral and presumably by its branch, the Lateral posterior choroid artery. The Choroid membrane in the descending cornu in front of the posterior surface of the Crus cerebri is supplied usually by the Anterior choroid artery, while the rest of the membrane is supplied from the Posterior cerebral through the Posterior choroid arteries.

The account given above agrees with the description given by DURET rather than that of KOLISKO, but, contrary to DURET's opinion, I have never found that the vessels of the choroid membrane "end in the caput of the corpus striatum and supply this freely and anastomose with the arteries of the anterior perforated spot," as the caput in my observations is never supplied by the Posterior choroid arteries (see p. 7).

As the Choroid plexus is supplied by the Anterior choroid, and also by the Posterior choroid arteries, there is a communication between these two sets of arteries. In two cases I have exposed the lateral ventricle, and have then injected the Anterior choroid artery from the Internal carotid with carmine and the Posterior cerebral with Nicholson's blue. When the former was injected alone, the carmine from the Anterior choroid was seen to extend along the whole length of the plexus as far as the foramen Monroi; on then clamping the Anterior choroid tube and injecting the Posterior cerebral artery, the Choroid membrane was seen to be injected, but the pressure was not sufficient to displace the carmine injection mass, owing to the free escape of the blue injection mass from the branches of the Posterior cerebral, which were cut in exposing the lateral ventricle.

I have observed, however, that it is more easy to inject the part usually supplied by the Anterior choroid artery from the Posterior cerebral artery than the reverse, as out of nine cases where the Anterior choroid artery was ligatured near its origin, the

part which is usually supplied by this artery was supplied in every case except one by the Posterior cerebral artery, whereas in the two cases where the Anterior choroid was injected, but not the Posterior cerebral, the part of the choroid membrane and plexus usually supplied by the Posterior cerebral remained uninjected. There thus seems in most cases a free communication between the Posterior cerebral artery and the Anterior choroid artery, and it would not be possible to determine the correct distribution of each unless the Anterior and Posterior choroid arteries were injected simultaneously with the same pressure.

The *Corpus geniculatum internum* was in every case supplied by the Posterior cerebral artery.

The *Corpus geniculatum externum* was supplied by the Posterior cerebral artery in every case except in four (out of 23 cases), where it was supplied by the Anterior choroid artery, which was here separately injected.

In connection with this distribution, the *Optic tract* was in all cases, where the Anterior choroid artery was separately injected, supplied by this artery up to its entry into the Corpus geniculatum externum (Plate 4, fig. 8, C. g. e.).

The *Fornix*.—The body (Corpus) was supplied in all cases by the Posterior cerebral artery, except in five cases, where it was supplied by the Anterior cerebral artery. The Crus posterior was in all cases supplied by the Posterior cerebral artery, except in two cases, where the Anterior cerebral gave the supply. Of the Columna fornicis, or Anterior pillar, the lower part was supplied by the Posterior cerebral, while the upper part was nourished by the Anterior cerebral artery.

The *Septum pellucidum* was in all cases supplied by the Anterior cerebral artery.

The *Anterior commissure* was supplied, in all cases where it was injected, in its median part by the Anterior cerebral artery, in the outer part by the Middle cerebral artery, and in the extreme posterior outer part by the Anterior choroid artery.

The basal arterial supply to the brain may, therefore, be arranged in zones or areas of distribution. Starting with the supply of the Posterior communicating artery to the Regio subthalamica as the centre nearest to the middle line, we have in the next zone the Anterior choroid area and the Anterior cerebral area, and external to these the Middle cerebral area. This arrangement is seen best in coronal sections (Plate 6, fig. 11).

The Cortical Distribution.

As has been pointed out by DURET* and other observers, the anastomosis between the vessels—anterior, middle, and posterior cerebral arteries—supplying the three principal areas is sufficiently free to allow the area of the anterior or posterior cerebral arteries to be injected from the middle cerebral artery, and therefore, in using soluble colours by which alone the finest capillaries can be injected, I would submit that it is essential that the injections of the different arteries should be made simultaneously with the same pressure, as has been done in the present research.

* *Loc. cit.*, p. 319.

I can confirm by several observations that the areas of the anterior and the posterior cerebral arteries can be injected from the middle cerebral artery, and also that the middle cerebral area can be injected from either the anterior or the posterior cerebral arteries. From the injection of the anterior cerebral artery alone on one side, the colouring matter has not reached the posterior cerebral area, though I have no doubt it would be possible with a longer continued injection.

This communication between the areas of two different arteries is well shown by the following observation, which I have repeated several times. If the anterior, middle, and posterior cerebral arteries be injected with three different colours and with the same pressure, until there is a well-marked line of demarcation—let us say—between the middle and the posterior cerebral areas, and if now the tube supplying the middle cerebral artery be clamped, it will be seen that the injection from the posterior cerebral area will invade that of the middle cerebral area and drive its colour out, but on releasing the clamp on the middle cerebral artery tube, the invading injection from the posterior cerebral area will be driven back until the original border line is attained.

DURET* states that he has never found an anastomotic network in the pia mater, although HEUBNER† and other anatomists describe such a network (Kanalnetzwerk). To determine this question, I have made the following experiment. The third branch of the middle cerebral artery, viz., the ascending parietal branch, was ligatured close to the Sylvian fissure, and the anterior, middle and posterior cerebrals were then simultaneously injected after cutting out the posterior communicating artery. It was found on subsequently cutting the hardened brain horizontally that the convolutions supplied by this ascending parietal branch were injected by the coloured gelatine from the anterior cerebral artery. This would show that either there is no communication between the contiguous branches of the middle cerebral artery, or that the communication is so slight that it is easier for the blood to reach the area corresponding to the ligatured artery from the branches of the anterior cerebral than from the contiguous branch of the same artery, or, in other words, that the communication between the middle cerebral artery and the anterior cerebral artery, where their areas touch, is much more free than that between the contiguous branches themselves of the middle cerebral artery.

I have made several observations to determine if the fine arteries of the cortex communicate with each other after they have entered the brain substance, and I find that there is no evidence that these fine vessels have any intercommunication when they have penetrated the cortex. So that if the pia mater be carefully stripped off the cortex over a small area, or a circular incision be made through the pia mater, that part of the cortex denuded of membrane, or the part inside the circle, will not be injected and will not receive any blood from the small cortical arterioles in the

* *Loc. cit.*, p. 318.

† 'Die Luetische Erkrankung,' etc., p. 187.

brain substance surrounding this area. The arterioles, therefore, after they enter the cortex, are end-arteries, and do not anastomose with their neighbouring arterioles.

As was shown by DURET, the cortical and basal systems are quite distinct and do not anastomose, and I am unable to find any anastomosis between the cortical and basal arteries when these are separately injected (Class I, p. 15).

Distribution of the Cortical Arteries.

The *Anterior cerebral artery* supplies the gyrus rectus of the Orbital surface lying on the inner side of the Olfactory sulcus, and also the convolution on its outer side, but not as a rule the inner, middle, and outer orbital gyri, which are supplied by the Middle cerebral artery; though in a certain number of cases the inner orbital gyrus is also supplied by the Anterior cerebral.

The Anterior cerebral artery then winds round to the median surface of the hemisphere in front of and above the Corpus callosum, and its extent posteriorly is given in the following table, the numerals giving the number of different brains in which the different distribution was observed :—

	Cases.
To half way along the Lobulus quadratus (præcuneus) (fig. 1)	21
To the Fissura parieto-occipitalis interna (fig. 2)	19
To the Fissure of ROLANDO (fig. 2).	8
	48

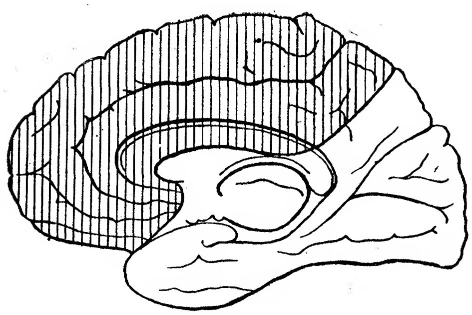


FIG. 1.—Anterior Cerebral Artery. Most frequent distribution on median surface. Shading denotes the most frequent distribution.

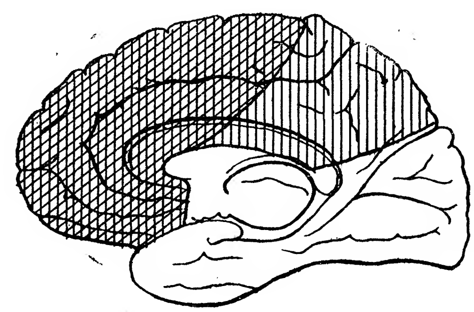


FIG. 2.—Anterior Cerebral Artery. Vertical lines denote maximal, and oblique lines minimal, distribution.

It will be seen from this table that in 40 of the cases examined the Anterior cerebral area extended along the median edge of the hemisphere as far posteriorly as the Fissura parieto-occipitalis interna, or to an inch anterior to this. From this point, along the median edge of the hemisphere, the posterior limit of this area extended obliquely forwards to the Corpus callosum, the body of which was supplied by the Anterior cerebral artery in all cases, except three in which the posterior part of the body was supplied by the Posterior cerebral artery.

On the outer surface, the area supplied by the Anterior cerebral artery varied considerably. Posteriorly it extended :—

	Cases.
To a point half way along the Gyrus parietalis superior (fig. 3) in . .	20
To the Fissura occipito parietalis externa (fig. 4) in	13
To the Fissura Rolandi in	11
To the Sulcus præcentralis superior in.	6
For the Anterior half of Gyrus frontalis superior (fig. 4) in	2
	52

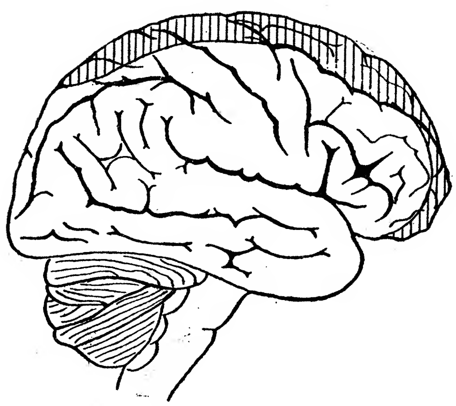


Fig. 3.—Anterior Cerebral Artery. Outer surface. Most frequent distribution.

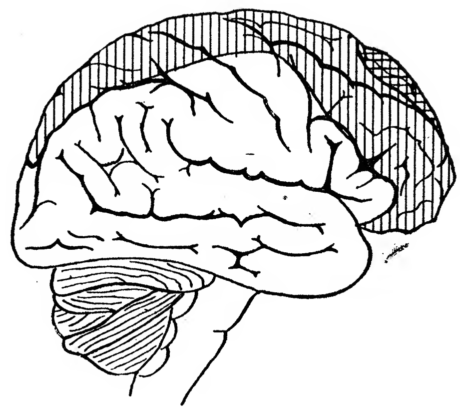


Fig. 4.—Anterior Cerebral Artery. Outer surface. Vertical shading denotes maximal, and cross shading minimal, distribution.

It will thus be seen that the majority of cases extended to half way along the Gyrus parietalis superior, which is more posterior than the limit given by Duret (upper part of Fissure of Rolando).

The extent of the Anterior cerebral area outwards and downwards on the outer surface of the hemisphere is shown in the following table :—

	Cases.
To the Sulcus frontalis superior in	40
To the middle of the Gyrus frontalis medius in.	15
To the Sulcus frontalis inferior in	7
To a line drawn horizontally through the middle of the Gyrus frontalis superior in	4
	66

This distribution differs from that given by Duret,* who describes the Internal and Anterior frontal artery as being distributed as far down as the Inferior frontal sulcus. In my observations, therefore, the Anterior cerebral artery supplies, in two-thirds of the cases, only the Superior frontal gyrus, and only one case in nine

* *Loc. cit.*

corresponded to the distribution given by DURET. In some of the 40 cases which extended to the Sulcus frontalis superior, the area of the Anterior cerebral artery extended to the Middle frontal gyrus in its most anterior part.

The *Middle cerebral artery*, as it winds round the fissura Sylvii, supplies the outer part of the orbital surface, and also the anterior part of the temporal lobe—the extent of its distribution on the inferior surface, and the border line between its area and that of the Posterior cerebral artery, is given under the description of the Posterior cerebral artery (p. 34). The area supplied by the Middle cerebral artery varies very much in different hemispheres. Its extent superiorly and anteriorly has been given in the account of the anterior cerebral distribution (p. 31), viz., to the superior frontal sulcus in most cases, and it was there shown that the Anterior cerebral area extends posteriorly in most cases to the anterior half of the gyrus parietalis superior. As the area supplied by the Posterior cerebral artery (p. 35) extends anteriorly to the external parieto-occipital fissure, or, in many brains, along the gyrus parietalis superior, so as to meet the area supplied by the Anterior cerebral artery, the Middle cerebral area in many cases does not reach the middle line. I have found out of 51 cases that the Middle cerebral reached the middle line in 30 cases (fig. 5), and did not do so in 21 cases. We have, therefore, every variety between the case of the area supplied by the Middle cerebral reaching the middle line for the distance from the superior præcentral sulcus to the external parieto-occipital fissure, and the case of the Middle cerebral area not reaching the middle line at all. In rare cases, the Middle cerebral area reaches the middle line just in front of the superior præcentral sulcus, then the upper parts of the two central gyri are supplied by the Anterior cerebral artery, while the superior parietal gyrus is supplied by the Middle cerebral.

DURET,* in his diagrams, fig. 3, p. 327, fig. 4, p. 328, carries the area supplied by the fourth branch of the Middle cerebral artery to the middle line, taking in the posterior half of the superior parietal gyrus, yet in the text he says that "above it (the fourth branch) supplies the inferior parietal convolution, and does not pass beyond the intraparietal sulcus" (p. 328). On p. 326 he states that the third branch of the Middle cerebral artery "often supplies the anterior part of the first parietal convolution." As in fig. 4 the area supplied by the Posterior cerebral does not extend forward beyond the external parieto-occipital fissure, there is no description of the artery which supplies the posterior part of the superior parietal gyrus.

The extent of the Middle cerebral area posteriorly towards the occiput varies very much in different hemispheres, and I have arranged the varieties in the following table in the order from the most extreme extent in that direction to the least extent. The area was measured in most cases along a horizontal line drawn from the upper end of the Fissura extrema of the Calcarine fissure to the angle of the Parallel sulcus :—

* *Loc. cit.*

		Cases.	Total.
To the occipital pole and round to the median surface .	in	1	
To the occipital pole (fig. 6)	in	19	
To $\frac{1}{4}$ or $\frac{1}{2}$ inch anterior to the occipital pole (fig. 5) .	in	12	
		———	32
To the Intraparietal sulcus, posterior end, where it is continued into the anterior occipital sulcus .	in	19	19
To the angle formed by the upturned end of the Parallel sulcus	in	23	
To a point anterior to the angle of Parallel sulcus .	in	2	
To a line drawn from the posterior end of the Sylvian fissure to the median line in the middle of the superior parietal gyrus (fig. 6) .	in	1	
		———	26
			—
			77

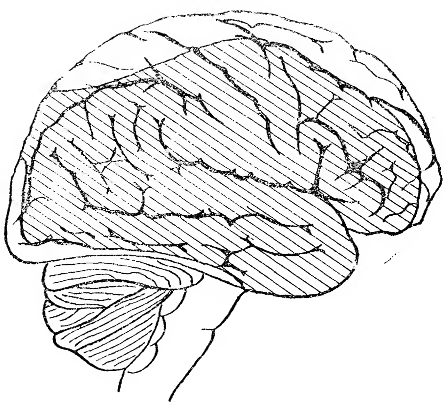


FIG. 5.—Middle Cerebral Artery. Outer surface. Area of most common distribution shown by shading.

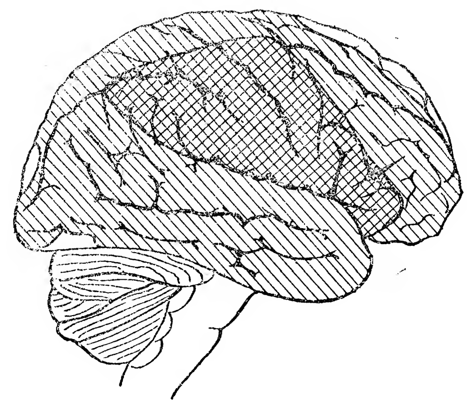


FIG. 6.—Middle Cerebral Artery. Outer surface. Area of maximal distribution shown by single lines, minimal by crossed shading.

The minimal distribution is not that of any one brain, but it is compounded of all the minimal distributions observed. The maximal distribution would represent that of one extreme case if the anterior cerebral area was made to extend posteriorly to the Rolandic fissure and externally to the superior frontal sulcus.

Dividing the cases into those in which the Middle cerebral area extends to, or within $\frac{1}{2}$ inch of, the occipital pole, in which it reaches to the level of the anterior occipital sulcus from 1 to $1\frac{1}{2}$ inch (2·5–3·8 cm.) from the pole, and in which it reaches to the upturned angle of the parallel sulcus about 2 inches (5 cm.) from the posterior pole, we find that the preponderance is in favour of the occipital pole

and $\frac{1}{4}$–$\frac{1}{2}$ inch anterior to it, and then for the angle formed by the parallel sulcus.* As will be seen later on, this distribution is of great importance in determining the supply of the optic radiations. The greatest extension of the Middle cerebral area in this direction was to the median surface for the posterior $\frac{1}{4}$ inch of the Cuneus, and the least was to the Fissure of SYLVIUS.

The extent of the Mid cerebral area downwards varies considerably, and is shown in the accompanying table:—

	Cases.
To the middle of the gyrus temporalis inferior (third) (fig. 5) . .	26
To the lower border of the gyrus temporalis medius (second) . .	21
To the lower border of the gyrus temporalis inferior (third) . . .	15
To the middle of the gyrus temporalis medius (second)	2
To the fissura Sylvii (fig. 6)	1
	65

It will be seen from the above that in all the cases, except three, the border line between the Middle and Posterior cerebral areas is in the third or inferior temporal gyrus, most frequently at its middle, next at its upper border, and then at its lower border.

This result differs from the extent given by DURET, viz., the middle of the gyrus temporalis medius. The extent of the area given above in the occipital direction also differs from that given by DURET, who continues the line back from the middle of the second temporal gyrus just behind the upturned parallel sulcus to the external parieto-occipital fissure.

The *Posterior cerebral artery* supplies the median and inferior surfaces of the temporal and occipital lobes, and in most cases extends on to the outer surface of the occipital lobe. On the inferior surface of the temporal lobe the line between the Middle cerebral and the Posterior cerebral areas extends outwards, as we saw above, to the middle of the gyrus temporalis inferior in most cases, and when this border is traced forwards it forms a curve convex forwards around the anterior end of the third temporal sulcus, and thence to the sulcus collateralis and across the substantia reticularis alba of the gyrus hippocampi to the base of the uncus and the hippocampal fissure (fig. 7). The area of the Posterior cerebral artery ascends posteriorly along the gyrus hippocampi across the posterior part of the corpus callosum to the border-line, between this area and that of the Anterior cerebral artery, drawn from this point to the internal parieto-occipital fissure or for an inch anterior to it (p. 30).

On the outer surface the area differs in shape according to the amount of extension backwards of the Middle cerebral area. As was shown on a previous page (p. 33),

* Although the parallel sulcus has the highest number, 23, it will be found that if the horizontal line be divided into half inches, the half inch next to the posterior pole will claim more cases, 32, than the half inch at the angle of the parallel sulcus.

the Posterior cerebral area did not extend on to the outer surface at all at the horizontal level of the posterior pole in 19 cases out of 77, and did not even reach the occipital pole on the median surface in one case, while in 12 it extended for $\frac{1}{4}$–$\frac{1}{2}$ inch from the occipital pole on to the outer surface along a line drawn from the upper end of the fissura extrema of the calcarine fissure to the angle of the parallel sulcus. In 19 cases the Posterior cerebral area extended to the intra-parietal or the anterior occipital sulcus, and in 23 to the angle of the Parallel sulcus, while in three cases it was anterior to this point.

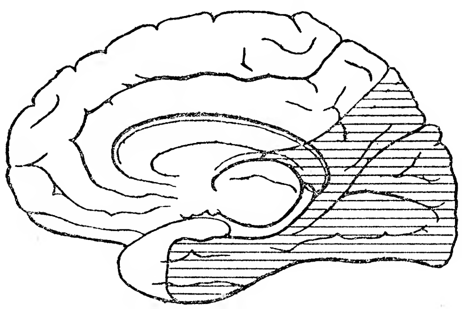


FIG. 7.—Posterior Cerebral Artery. Median surface. Shaded area shows the most common distribution.

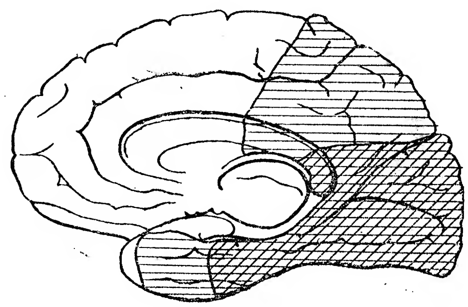


FIG. 8.—Posterior Cerebral Artery. Median surface. Horizontal shading shows maximal, and crossed shading minimal, distribution.

The Posterior cerebral artery area also, in many cases, extends forwards along the outer surface near to the middle line, and this is shown in the following table arranged postero-anteriorly along the median line, excepting the three last numbers :—

	Cases.
To a point half way between the occipital pole and the parietal-occipital fissure	6
To the fissura parieto-occipitalis externa (fig. 9)	24
To $\frac{1}{4}$ inch anterior to this fissure	8
To $\frac{1}{2}$ inch anterior to this fissure	3
To half way between the external parieto-occipital and Rolandic fissures	10
To $\frac{1}{2}$ inch (1·25 cm.) posterior to Rolandic fissure (fig. 10)	5
To Rolandic fissure	1
On posterior part of third temporal gyrus only	2
Not on external surface	1
	60

Here the most frequent point is the external parieto-occipital fissure, in 24 hemispheres, which corresponds to DURET's description, but it must be noted that in 27 cases the Posterior cerebral extended anteriorly to this fissure. It was seen that, in all cases except one, the area in its inferior part extended anteriorly along the inferior temporal gyrus. The commonest form for the area of the Posterior cerebral

artery on the outer surface to take is that of a ⊏ with the concavity forwards. In those cases (20 in 77) where the middle cerebral area reached to the occipital pole, the bottom of the ⊏ was broken through, and in those cases where the Posterior cerebral artery extended on to the outer surface along the line of the parallel sulcus, the concavity of the ⊏ was filled up, and the shape became triangular, till in one extreme case all the cortex posterior to a line drawn from the posterior end of the Sylvian fissure to the middle of the superior parietal gyrus was supplied by the Posterior cerebral artery.

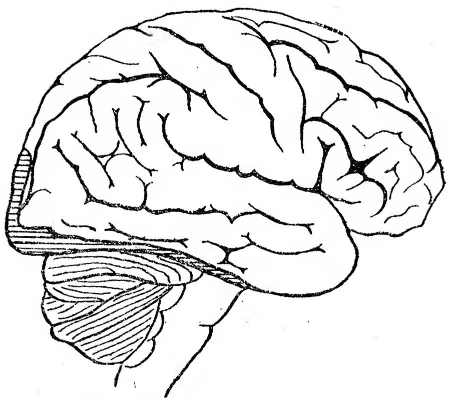


FIG. 9.—Posterior Cerebral Artery. Outer surface. Most frequent distribution shown by shading.

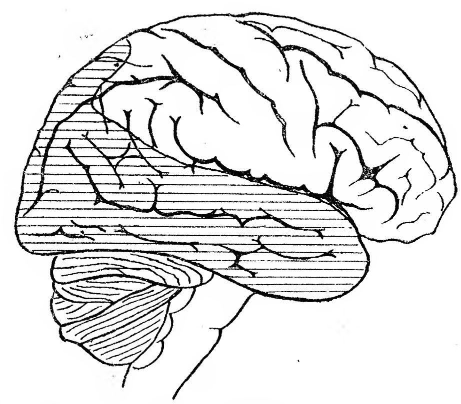


FIG. 10.—Posterior Cerebral Artery. Maximal distribution on outer surface.

This diagram is not taken from the distribution of one brain, but is compounded of all the maximal distributions.

In connection with the supply of the occipital cortex is the very important question of the supply of the interior of the occipital lobe, and particularly of the optic radiations.

Optic Radiations.

The white matter of the interior of the occipital lobe is supplied by the branches from the middle cerebral and posterior cerebral arteries to the occipital cortex. These cortical branches send small arteries through the cortex into the white matter, and the question is how much of this white matter, and particularly how much of the optic radiations, is supplied by the middle cerebral and how much by the posterior cerebral artery. According to VON MONAKOW,* "a complete integrity of the optic radiations has never been seen in lesions of the calcarine fissure where hemianopia was present . . . a blocking of the calcarine artery causing necrosis of the whole calcarine cortex would produce a lesion of the optic radiations . . . there would be a permanent hemianopia only when the optic radiations were affected either in the posterior horn or in their position behind the ventricle. A pure cortical hemianopia is anatomically impossible." According to MONAKOW,* the optic radiations are supplied almost entirely by the posterior cerebral.

* 'Gehirn-Pathologie,' p. 464.

According to HENSCHEN,* who has made numerous injections—I have not been able to ascertain the method used by him—the nutrition of the median surface of the occipital lobe is supplied chiefly by the posterior cerebral artery, which also gives the principal supply to the ventral part of the optic radiations, while the supply of the lateral part of the occipital lobe (? outer surface) is chiefly by the middle cerebral artery, which also supplies largely the middle part of the optic radiations measured from below upwards. He considers that the injection mass can pass from the posterior cerebral artery to the middle cerebral artery, and *vice versâ*; that numerous anastomoses exist between the two areas, especially on the exterior; that all the optic radiations can be injected from above downwards, not only from the posterior cerebral, but also from the middle cerebral artery. That the whole of the point of the lobe (? occipital pole) can be well injected by the two sets of vessels; that a capillary injection of the calcarine cortex can be made from the middle cerebral artery through the little arteries which pass into the medullary substance and optic radiations which are supplied by the middle cerebral artery, and that this area of the median surface of the occipital lobe has also numerous communications with the Anterior cerebral artery, so that from this artery it is possible to supply the posterior cerebral and the middle cerebral arterial area as far as the point of the lobe, also a part of the calcarine cortex, as well as the greater part of the optic radiations. He concludes that MONAKOW's idea—that an exclusively cortical lesion of the cortex around the calcarine fissure is an anatomical impossibility—is against anatomical researches and evident pathological facts.

He also thinks (p. 83)* that the seat of the representation of the macula of the retina is probably in the anterior part of the occipital lobe, and especially the part within the calcarine fissure, *i.e.*, the gyrus or pedunculus cunei. This part would be, he thinks, specially favoured for nutrition, as it could derive its blood supply from three different arteries (anterior, middle, and posterior cerebral), whereas the posterior part of the calcarine fissure could get its supply from only two different arteries, the middle and posterior cerebral arteries; and this would explain why the vision for the macular region so often escapes in cases of hemianopia.

I have, therefore, made observations to determine: (1) The distance of the gyrus or pedunculus cunei—the apex at the anterior end of the cuneus, which is anterior to the junction of the internal parieto-occipital and calcarine fissures, and which can only be seen, on separating the lips of the calcarine fissure, to be lying on the floor of this fissure—from the areas of the middle and anterior cerebral arteries, and the distance of the anterior and posterior parts of the cortex forming the floor of the calcarine fissure from the middle cerebral artery. (2) The supply of the optic radiations, and the relative shares taken by the middle and posterior cerebral arteries.

(1) The normal supply of the gyrus cunei and of the cortex round the calcarine fissure is from the Posterior cerebral artery. Taking first the distance of the gyrus

* 'Le Centre Cortical de la Vision,' 1900, p. 64.

cunei from the anterior and middle cerebral areas, I have examined in 23 cases the distance of the base of the gyrus cunei from the nearest anterior cerebral arterial area, viz., that of the gyrus fornicatus. In 14 cases the distance was 1 inch (2·5 cm.), in six it was $\frac{1}{2}$ inch, and in three it was from $2\frac{1}{4}$ to 3 inches. Out of 22 cases which I examined, the base of the gyrus cunei was in contact with the middle cerebral area in nine cases, in six cases it was $\frac{1}{4}$–$\frac{1}{2}$ inch distant from it, in five cases 1 inch, and in two cases there was a distance of from $1\frac{1}{2}$ to 2 inches between the base of the gyrus cunei and the nearest middle cerebral area.

I have also ascertained the distance of the cortex of the anterior and posterior parts of the calcarine fissure from the area of the middle cerebral artery. Taking the cortex of the anterior part of the calcarine fissure which is adjacent to the internal parieto-occipital fissure, out of 23 cases the cortex on the floor of the calcarine fissure was in contact in nine cases with the middle cerebral area supplying the internal medulla of the occipital lobe, in two cases the area was $\frac{1}{8}$ inch from the cortex, in five cases $\frac{1}{2}$ inch, in four cases 1 inch, in three cases $1\frac{1}{4}$–2 inches. The distance of the posterior part, and the fissura extrema, of the calcarine fissure was examined in 18 cases; in two cases the cortex at the bottom of the fissure was in contact with the middle cerebral area, in two cases it was $\frac{1}{4}$ inch away, in seven cases $\frac{1}{3}$–$\frac{1}{2}$ inch, in three cases 1 inch, and in four cases 2–$2\frac{1}{2}$ inches. It will thus be seen that in the majority of cases the supply to the calcarine cortex can be easily supplemented by the middle cerebral artery, and also that the gyrus cunei and the anterior half of the cortex forming the floor of the calcarine fissure is more often in contact with the area of the middle cerebral artery than the posterior half of the calcarine cortex, and thus this is in favour of HENSCHEN'S contention that the gyrus cunei is, while supplied by the posterior cerebral artery, nearer to the areas of the middle and anterior cerebral arteries, than is the cortex bounding the posterior half of the calcarine fissure.

(2) The other point to determine was the supply of the *optic radiations*, and especially of the part lying posteriorly to the lateral ventricle. This could only be accurately ascertained in coronal sections, and the following account refers only to coronal sections.

It was shown on p. 33 that the distribution of the middle cerebral artery to the cortex on the outer surface of the parietal and occipital lobes varies very much in different hemispheres, and I have found that the supply to the optic radiations corresponds to the supply of the cortex, so that when the area of the middle cerebral does not extend on the outer surface further towards the occipital end than the Sylvian fissure, or to a point situated between this and the parallel sulcus, the supply of the optic radiations is almost entirely by the posterior cerebral artery and not by the middle cerebral, whereas when the area of the middle cerebral extends to the occipital pole the supply to the optic radiations from this artery preponderates over that of the posterior cerebral. I have examined 15 injected brains cut coronally, and

of these brains in six the middle cerebral area on the outer surface extended to the occipital pole or to 1/4 inch from it, in six cases this area reached the posterior part of the intra-parietal sulcus, in two cases it reached the upturned end of the parallel sulcus, and in one case to the Sylvian fissure.*

The most common distribution, which occurred six times, was as follows. In front of the coronal section through the junction of the internal parieto-occipital fissure with the calcarine fissure, the upper three-fourths of the optic fibres, as seen in the coronal plane, were supplied by the middle cerebral artery while the inferior one-fourth was supplied by the posterior cerebral artery. Posteriorly to the internal parieto-occipital fissure the upper three-fourths of the fibres were supplied by the middle cerebral for the anterior one-third of the distance (which measures on an average $1\frac{1}{2}$ inches) from this fissure to the fissura extrema of the calcarine fissure; while for the posterior two-thirds of this distance these fibres were supplied by the posterior cerebral artery. The whole of the inferior one-fourth of the fibres behind the internal parieto-occipital fissure were supplied by the posterior cerebral artery. In other words, the superior three-fourths of the fibres, which comprises those which go to the cortex of the cuneus on the superior lip of the calcarine fissure, were supplied by the middle cerebral, with the exception of the posterior 1 inch (2·5 cm.) which was supplied by the posterior cerebral, while all the inferior one-fourth of the optic radiations, which end in the cortex of the gyrus lingualis, were supplied by the posterior cerebral artery. In two other cases the supply of the middle cerebral artery to the superior three-fourths of the optic radiations extended to the anterior one-sixth and one-half respectively of the distance between the internal parieto-occipital fissure and the fissura extrema. Therefore, in 8 out of the 15 cases examined, the middle cerebral artery supplied the superior three-fourths of the optic radiations from the part in front, supplied by the anterior choroid artery, to a point behind, which lies from one-sixth to one-half of the distance measured along the calcarine fissure from the internal parieto-occipital fissure to the fissura extrema. In three other cases the middle cerebral artery supplied not only the upper three-fourths of the optic radiations along the anterior half of the horizontal distance from the internal parieto-occipital fissure to the fissura extrema (in one case for one-sixth of this distance), but also the inferior one-fourth of its fibres to the same point posteriorly; so that in two of these cases all the optic radiations posteriorly to the part supplied by the anterior choroid artery were supplied by the middle cerebral artery, with the exception of the most posterior $\frac{3}{4}$ inch—and in one case of the posterior $1\frac{1}{4}$ inches—which had their supply from the posterior cerebral artery. In one case the inferior one-fourth of the radiations was supplied by the middle

* The relation between the supply of the posterior cerebral artery to the external surface and the prolongation of the line of GENNARI on to the external surface, I have examined in five cases. In all of these cases the posterior cerebral supply extended for 2 inches anteriorly to the occipital pole, but in none of them could the line of GENNARI be traced on to the external surface. (February 18th, 1908.)

cerebral to a point $\frac{1}{4}$ inch anterior to the internal parieto-occipital fissure. In all the 12 cases cited above, the area of the middle cerebral artery extended on the outer surface of the cortex either to the occipital or the intra-parietal sulcus (or the anterior occipital sulcus which it joins). Of the three remaining cases, in two the middle cerebral area reached posteriorly to the upturned end of the parallel sulcus or nearly to it, and in one only to the Sylvian fissure. In the two first of these cases the upper three-fourths of the radiations were supplied by the middle cerebral as far as the coronal level of the internal parieto-occipital fissure and posteriorly to it by the posterior cerebral. In the last case the posterior cerebral artery supplied all the optic radiations. I have also noted in other cases cut horizontally, where the middle cerebral area did not extend on the outer surface posteriorly to the parallel fissure, that the supply to the optic radiations was chiefly from the posterior cerebral artery.

On looking at the table on p. 33, it will be seen that the number of cases in which the middle cerebral artery reaches the occipital pole or within 1 inch of it is nearly double the number of those cases where it reaches to the angle of the parallel sulcus or not so far as that, and, therefore, the cases where the optic radiations are supplied alone by the posterior cerebral artery are in a decided minority.

The question therefore arises whether the circumstance that the whole vertical depth of the optic radiations for the posterior inch or $\frac{3}{4}$ inch of their course is supplied by the posterior cerebral artery would mean that all the optic radiations would have to pass through the area supplied by the posterior cerebral artery before reaching the calcarine cortex. The optic radiations have to pass round the end of the posterior cornu of the lateral ventricle from the outer side of this cavity to reach the calcarine cortex on the median surface of the hemisphere, and the question arises, how far posteriorly to the posterior end of the lateral ventricle do those optic radiations, which are supplied by the middle cerebral, extend? I have in five cases, which had been cut coronally, ascertained this point. In two cases the extent was $1\frac{1}{8}$ inch, in another case 6/8 inch, in another 1/2 inch, and in the last case only 3/16 inch. There is, therefore, in some cases ample room for the upper two-thirds of the optic radiations, which are supplied by the middle cerebral artery, to reach the calcarine cortex without passing through the area supplied by the posterior cerebral artery.

It must be stated that, according to FLECHSIG, the fasciculus longitudinalis inferior belongs to the projection system of fibres, its fibres connecting the occipital cortex with the optic thalamus. This opinion is supported by REDLICH* and by ARCHAMBAULT.† I have found that the arterial supply of this tract corresponds very closely to that of the optic radiations, so that the anterior superior external part is supplied by the middle cerebral and the inferior together with the posterior part by the posterior cerebral artery.

My observations would therefore agree with those of both MONAKOW and

* 'Arb. neurol. Inst. Wien. Univ.,' vol. 10, p. 109.

† 'Rev. neurol.,' November 30, 1905, p. 1053.

Henschen (pp. 36 and 37), as in some of my cases the optic radiations could hardly escape if the occipital artery from the posterior cerebral was thrombosed, while in the majority of my cases a good part of the radiations would not be involved. As the lingual fibres are more supplied by the posterior cerebral artery than the cuneal, it ought to be more common to have superior "quadrantanopia" than hemianopia, if the loss of vision were due to involvement of the optic radiations rather than of the calcarine cortex, but at present there are only two cases* recorded with *post-mortem* verification of quadrantanopia and a cortical lesion. I would also wish to point out that in those cases, where all the optic radiations are supplied by the posterior cerebral artery, the branches to the radiations, which in other cases are supplied by the middle cerebral, may be here supplied by the posterior temporal branch of the posterior cerebral artery to the outer surface of the cortex. If in those cases where the posterior cerebral area is large the radiations were chiefly supplied by the posterior temporal artery, they would not be affected by blocking of the occipital or calcarine artery.† I should agree with Henschen that in most cases the middle cerebral supplies the upper one-third of the optic radiations while the lower one-third is supplied by the posterior cerebral, but I also found that the supply to the posterior part of the radiations is by the posterior cerebral, though in some cases it only comprises the most posterior $\frac{3}{4}$ inch of the cuneal fibres. With regard to the question of injecting all the optic radiations from the middle cerebral artery, I made the experiment of injecting the middle and anterior cerebral arteries with different colours after ligaturing the occipital artery of the posterior cerebral just anterior to the internal parieto-occipital fissure, and I found that the injection from the middle cerebral readily injected all the posterior cerebral area including the optic radiations. It seems, therefore, that the softening produced in pathological cases must, as Henschen has suggested, be due to a rapid extension of the thrombus into the minute arterioles or else to embolism of the fine arteries, for it is not possible to cut off the blood supply to the cuneus and gyrus lingualis by simply ligaturing the occipital artery, as the circulation to the posterior cerebral area can be so readily restored through the branches of the middle cerebral artery.

Corpus Callosum.—The arterial supply to this structure is obtained from the cortical vessels. The principal part or body of the corpus callosum was supplied in all cases by the anterior cerebral artery, with the exception of three cases in which its posterior part was supplied by the posterior cerebral artery. In one case the whole of the body up to the genu was supplied by the posterior cerebral artery.

* Hun, 'Amer. Journn. Med. Sciences,' January, 1887, vol. 93, p. 141; Beevor and Collier, 'Brain,' 1904, p. 153. In the last case the cortex, but not the optic radiations, was affected, which is against Monakow's view, p. 36.

† I have not yet determined whether the arterial supply to the inferior one-fourth of the optic radiations comes from the calcarine branch or from the posterior temporal branch of the posterior cerebral artery.

The *Genu* and *Rostrum* were in all cases supplied by the anterior cerebral artery. The *Tapetum* in the part nearest to the main part of the corpus callosum was supplied by the anterior or middle cerebral, in the external part by the middle cerebral, and in the posterior part outside the posterior cornu of the lateral ventricle by the middle or the posterior cerebral. The *Splenium* was supplied by the posterior cerebral in all cases, except in two by the anterior cerebral, and the *Forceps major* by the posterior cerebral in all cases, except in two by the middle cerebral artery.

There is one part of the Cerebral cortex, which is not supplied by the anterior, middle, or posterior cerebral arteries, and that is the *Uncus*, which is supplied by the anterior choroid artery. This artery comes off from the internal carotid, and courses outside the optic tract to the median surface of the temporal lobe. Out of 15 cases where the anterior choroid artery was separately and successfully injected, in all, except one when it was supplied by the posterior cerebral, the Uncus was injected by this artery. In most cases the area injected extended downwards to the horizontal level of the dentate fissure or half way between this fissure and the fissura collateralis, anteriorly it extended usually to the sulcus bounding the uncus anteriorly, but in one or two instances it extended forwards to the anterior extremity of the temporal lobe.

The *Cornu ammonis*, or Hippocampus major, has an arterial supply which is not the same in all cases. Of 15 cases in which the anterior choroid artery was separately and successfully injected, in seven the Cornu ammonis was supplied by the anterior choroid artery; of these cases, in one the whole of this body was supplied below the horizontal level of the corpora quadrigemina, and in six others the anterior inferior $\frac{1}{2}$ inch was alone supplied, the rest of this region in these six being supplied by the posterior cerebral artery. In the eight other cases the posterior cerebral artery supplied all the cornu ammonis. In relation to the anterior end of the cornu ammonis, it can be seen in horizontal and coronal sections (Plate 6, figs. 11 and 12) to make a sigmoid bend forwards and to join the *Nucleus amygdalæ*. This body and the sigmoid bend were supplied by the anterior choroid artery in all the cases where this artery was separately injected, and it is important to note that the nucleus amygdalæ, the surcingle or tail of the caudate nucleus, the inner segment of the lenticular nucleus, and the optic tract are all supplied by the anterior choroid artery.

The *Fascia dentata* was in nearly all cases supplied by the posterior cerebral artery.

The *Fimbria* was noted in four times to be supplied in its anterior inferior part by the anterior choroid, and in five—presumably by the anterior choroid—from the internal carotid, and in 14 times by the posterior cerebral artery, in its posterior part.

Centrum Ovale.—The arteries on the surface of the brain are divided by DURET* into cortical and medullary. The former end in the grey matter, and the latter pass through the grey matter of the cortex into the medullary white matter, which they supply, including the whole centrum ovale.† I have in four cases injected the arteries

* *Loc. cit.*, p. 334.

† The distribution to the centrum ovale is shown in figs. 9–20 in MONAKOW'S 'Gehirn-Pathologie.'

to the outer surface of the hemisphere beyond where their basal branches are given off, and in five cases I have injected the three chief arteries at their commencement, ligaturing them just beyond their basal branches, so as to inject only these branches. In confirmation of DURET'S* statement, it can be seen that when the cortical arteries are injected after having been ligatured beyond the basal branches, the injection extends through the whole depth of the centrum ovale, as far as the upper surface of the caudate and lenticular nuclei and the internal capsule, but without injecting them, while the converse is the case when the basal branches are alone injected. I can also confirm DURET'S statement* that the Claustrum and the external capsule are supplied by the cortical arteries, which penetrate from the Insula, and that there is no connection between the arteries to these structures and those of the adjoining lenticular nucleus. The optic radiations, as has already been stated (p. 36), are supplied by the middle and posterior cerebral arteries of the occipital cortex, which send their medullary arteries into the white substance of the occipital lobe. On injecting the basal arteries after ligaturing the posterior cerebral artery behind the basal arteries, the optic radiations posterior to the area supplied by the anterior choroid artery, were not injected, thus showing that the arterial supply comes from the Cortical arteries.

The distribution of the three chief arteries to the Centrum ovale corresponds to the cortical distribution of each artery. The exact area occupied by each artery, as seen in sagittal, horizontal, and coronal sections, is shown in Plates 1–7.

Summary.

Basal Branches.—Taking the distribution which was most frequently found, the *Regio subthalamica* (Plate 6, fig. 11), including the Corpus subthalamicum and FOREL'S field, was supplied by the Posterior communicating artery, and the *Corpus mammillare* by the Posterior cerebral artery. In the *Crusta* or *Pes pedunculi* the anterior one-third was supplied by the Posterior communicating artery and next in frequency by the Anterior choroid artery, and the posterior two-thirds mostly by the Posterior cerebral (Plate 6, fig. 12) and next by the Anterior choroid artery (Plate 4, fig. 8). In the *Internal capsule* the *anterior* segment was supplied by the Anterior cerebral for the inferior half and by the Middle cerebral in its superior half (Plate 5, fig. 9). The *posterior* segment of the internal capsule, below the level of the superior angle of the middle segment of the lenticular nucleus, was supplied in its anterior one-fourth or one-third by the Posterior communicating artery (Plate 6, fig. 11), and in its posterior three-fourths or two-thirds by the Anterior choroid artery (Plate 3, fig. 6). The *Retro-lenticular* (Plate 3, figs. 5 and 6, Plate 7, fig. 14, R. 1) *fibres* and the *Optic radiations* at their commencement were supplied by the Anterior choroid artery. The superior part of the posterior segment of the internal capsule above the level of the upper angle of the middle

* *Loc. cit.*, p. 79.

segment of the lenticular was supplied by the middle cerebral artery, and was continuous with the distribution of the middle cerebral artery to the upper anterior parts of the caudate and lenticular nuclei, and of the anterior segment of the internal capsule.

In the *Caudate nucleus* the Caput was supplied in its lower half by the Anterior cerebral artery, and in its upper half by the Middle cerebral artery. The superior horizontal part of the caudate nucleus was supplied by the Middle cerebral artery as far posteriorly as the vertical level of a coronal section made through the anterior part of the Pons (Plate 7, figs. 13, 14). Behind this level for $\frac{1}{4}$ inch the caudate nucleus was supplied by the Posterior cerebral artery, while the tail or surcingle was supplied by the Anterior choroid artery.

Of the *Nucleus lenticularis*, the external segment (Putamen) was in the main supplied by the Middle cerebral artery, but the anterior inferior part was in over half the cases supplied by the Anterior cerebral, the dividing line between the anterior and middle cerebrals being midway along the internal capsule at right angles to it as seen in coronal sections (Plate 5, fig. 9), while the posterior inferior part was in several cases supplied by the Anterior choroid artery.

The middle segment of the Nucleus lenticularis was supplied chiefly by the Middle cerebral artery; but in some cases the anterior inferior part was supplied by the Anterior cerebral artery, and occasionally the posterior part by the Anterior choroid artery (Plate 3, fig. 6).

The internal segment of the Lenticular nucleus was chiefly supplied by the Anterior choroid artery (Plate 3, fig. 6), but occasionally by the Posterior communicating and Anterior cerebral arteries.

In the *Optic thalamus* the anterior nucleus was supplied by the Posterior cerebral artery (Plate 6, fig. 11). The anterior external part of the external nucleus by the Posterior communicating artery (Plate 6, fig. 11); the posterior part of the external nucleus by the Posterior cerebral. The internal nucleus was supplied by the Posterior cerebral in its posterior half, and by this artery or the Posterior communicating in its anterior half (Plate 7, fig. 13). In some cases the whole anterior half was supplied by the Posterior communicating artery. The pulvinar was supplied by the Posterior cerebral (Plate 7, fig. 14).

The *Choroid plexus* was supplied by the Anterior choroid artery in the descending and posterior cornua of the lateral ventricle, and in the central part of the lateral ventricle by the Posterior cerebral. The *Choroid membrane* in the descending cornu, anterior to the coronal section through the anterior or the lateral part of the crus cerebri, was supplied by the anterior choroid artery, while the rest of the membrane was supplied by the posterior cerebral artery. So that, posterior to the coronal section through the lateral part of the crus, the choroid plexus in the descending cornu on the outer side of the fimbria was injected by the anterior choroid artery, while the choroid membrane on the median side of the fimbria was injected by the

posterior cerebral. The *Corpora geniculata* received their blood supply from the posterior cerebral artery; the *Optic tract* from the anterior choroid artery (Plate 4, fig. 8).

In the *Fornix* the body was supplied by the posterior cerebral, occasionally by the anterior cerebral artery; the columna fornicis was supplied in its inferior part by the posterior cerebral, and in its superior part by the anterior cerebral artery; the crus fornicis by the posterior cerebral. The *Septum lucidum* always by the anterior cerebral artery.

The *Anterior commissure* was supplied in its median part by the anterior cerebral, in the external part by the middle cerebral, and in the postero-external part by the anterior choroid artery.

Cortical Branches.—The area of the Anterior cerebral artery extended posteriorly along the median surface to half way along the lobulus quadratus or to the internal parieto-occipital fissure (21 cases to 19) (fig. 16), and on the external surface posteriorly to half way along the gyrus parietalis superior (lobulus parietalis) (figs. 15 and 17); inferiorly on the external surface to the sulcus frontalis superior, and in some cases for the anterior one-third of the frontal lobe to the middle of the second frontal gyrus. The area supplied by the middle cerebral artery on the outer surface was bounded antero-superiorly by the sulcus frontalis superior, superiorly it extended to the middle line along the posterior half of the gyrus parietalis superior (not shown in figs. 15 and 17), downwards to the middle of the third temporal gyrus, or to its superior border (fig. 18), and posteriorly it reached to the occipital pole or to $\frac{1}{4}$–$\frac{1}{2}$ inch anterior to it (fig. 15). The posterior cerebral artery supplied all the median surface of the temporal and occipital lobes, except the anterior end of the temporal, which was supplied by the middle cerebral, and the uncus, which was supplied by the anterior choroid (fig. 16); on the median surface the posterior cerebral area reached to the internal parieto-occipital fissure, or 1 inch anterior to this (fig. 16); on the outer surface near the middle line its area reached anteriorly to the external parieto-occipital fissure, or to a point between this and the middle of the superior parietal lobule (fig. 17), posteriorly to the occipital pole or to the intra-parietal sulcus (posterior part) (fig. 15), and inferiorly it reached to the middle or the superior border of the inferior temporal gyrus (fig. 18).

With regard to the optic radiations, the part nearest to the optic thalamus was supplied by the anterior choroid artery (Plate 3, figs. 5 and 6), while the part which courses round the posterior cornu was supplied by the cortical branches from the middle or posterior cerebral arteries, which sink into the white matter of the occipital lobe. In most cases the middle cerebral artery supplied the superior three-fourths, and the posterior cerebral the inferior one-fourth, of the optic radiations—as seen in coronal section—with the exception of the posterior 1 inch or $\frac{1}{4}$ inch, where all the fibres were supplied by the posterior cerebral artery. In a fewer number of cases the posterior cerebral artery supplied all the optic radiations.

With regard to the distance of the gyrus cunei and the cortex forming the floor of the calcarine fissure—which were supplied by the posterior cerebral—from the areas supplied by the anterior and middle cerebral arteries respectively, it was found that in most cases the gyrus cunei was about 1 inch from the anterior cerebral area, and that its base was in contact with the middle cerebral area. The relations of the anterior part of the floor of the calcarine fissure were similar to that of the gyrus cunei, while in the case of the posterior part of the fissure it was in most cases $\frac{1}{3}$–$2\frac{1}{2}$ inches distant from the middle cerebral area.

Of the Corpus callosum, the Genu, Rostrum, and Body were supplied by the cortical branches of the anterior cerebral artery (fig. 16); the Tapetum nearest to its origin was supplied by the anterior or middle cerebral, its external part by the middle cerebral, and the posterior part by the middle cerebral (Plate 2, fig. 4), or by the posterior cerebral artery: while the splenium and Forceps major were supplied by the posterior cerebral artery (Plate 3, figs. 5 and 6).

In comparing my observations with those of previous workers, I would draw attention to the following points. I believe that the method of injecting the arteries simultaneously and under the same pressure with gelatine containing soluble colours has not been employed before for cerebral injections. The arterial supply of the Regio subthalamica, including the Corpus subthalamicum and FOREL's field, have not been described, and the relative shares of the Anterior choroid, Posterior communicating, and Posterior cerebral arteries in the arterial supply of the Crus cerebri have not been given before. The Corpus mamillare I find to be supplied more often by the Posterior cerebral than by the Posterior communicating arteries (DURET and HEUBNER). In the Internal capsule, the exact supply to the anterior limb by the Anterior and Middle cerebral arteries is ascertained in my investigations to supply respectively the inferior and superior halves; previously this part had been described by HEUBNER as being supplied by the branches from the fork between the Anterior and Middle cerebral arteries. In the posterior limb of the internal capsule, and in the retro-lenticular fibres, I agree with the supply given by KOLISKO, but I do not find that there is any anastomosis between the three arteries supplying the posterior limb of the internal capsule. I also find that in some cases the posterior cerebral artery supplies part of the posterior two-thirds of this limb.

In the Caudate nucleus, although the anterior cerebral artery was considered by the three observers quoted to supply the head of this nucleus, the exact share taken by the anterior and middle cerebral arteries had not been ascertained, nor had the exact distribution of the middle cerebral, posterior cerebral, and anterior choroid arteries to the rest of the caudate nucleus been observed. I cannot agree with DURET that the head of this nucleus is ever supplied by the posterior cerebral artery through the Choroid membrane, or that this artery anastomoses there with the Anterior cerebral.

In the Lenticular nucleus I cannot find any evidence of the internal branches to the corpus striatum from the middle cerebral artery (DURET), and I agree in the main

with KOLISKO, but I find that the outer and middle segments are sometimes supplied in their posterior part by the anterior choroid artery, and that the anterior part of the middle and internal segments are sometimes supplied by the anterior cerebral artery.

As to the Optic thalamus, no attempt has been made by previous observers to work out the vascular supply to the different nuclei, but I find that the external nucleus in its anterior superior external part is supplied more frequently by the posterior cerebral instead of by the posterior communicating (KOLISKO), while its anterior external part is supplied by the posterior communicating artery. My observations agree with KOLISKO, that the optic thalamus is exceptionally—I should say very rarely—supplied by the anterior choroid artery. It is not supplied by the lenticulo optic arteries of DURET.

With regard to the Choroid plexus and membranes, my observations agree with those of DURET rather than those of KOLISKO, but I find that the anterior part of the choroid membrane in the descending cornu is supplied by the anterior choroid, also that there is a free communication between the anterior choroid and posterior lateral choroid arteries supplying the choroid plexus, so as to inject the former from the latter. As stated above, I have never found the vessels of the choroid membrane to end in the caput of the corpus striatum and to anastomose with the arteries of the anterior perforated spot (DURET). The exact vascular distribution to the Fornix and anterior commissure has not been given before.

In the Cortex my observations agree with those of DURET, viz., that while the basal branches are end-arteries, there is an anastomosis between the cortical arteries at the borders of the different areas; I find, moreover, that this communication is more free than that between the contiguous branches of the same artery. This is therefore against the opinion of HEUBNER that there is an anastomotic network in the pia mater. I also agree with DURET'S view that the cortical arterioles become end-arteries as soon as they enter the cortical substance. My observations show that great variation is met with in the cortical arteries, but, taking the distribution found in the greatest number of cases, my results differed from those of DURET in the following particulars: the Anterior cerebral area extends on the external surface posteriorly to midway between the fissure of ROLANDO and the external parieto-occipital fissure, instead of to the fissure of ROLANDO, while it extends outwards and downwards to the superior frontal sulcus, instead of to the inferior frontal sulcus. The Middle cerebral area reaches the middle line only along the posterior half of the superior parietal lobule, and not along its whole extent, as figured by DURET. Posteriorly this area extends rather more frequently to the occipital pole, or to $\frac{1}{2}$ inch anterior to it, than to the up-turned posterior end of the parallel sulcus (DURET). Inferiorly this area extends to the middle or upper border of the inferior temporal gyrus, rather than to the middle of the middle temporal gyrus (DURET). The Posterior cerebral area on the external surface extends to the external parieto-occipital fissure, agreeing with DURET, but, in almost an equal number of cases it extends to various points anterior to this fissure.

My observations on the arterial supply to the pedunculus vel gyrus cunei agree with those of HENSCHEN, that this part of the cuneus is more intimately related to the middle and anterior cerebral areas than the rest of the cuneus, and also that the supply of the optic radiations is obtained more frequently from both the middle and posterior cerebral arteries (middle and ventral parts of radiations) than from the posterior cerebral alone, as figured by MONAKOW. More exactly, the superior three-fourths of the optic radiations, as seen in coronal section in the occipital region, are supplied by the middle cerebral, and the inferior one-fourth by the posterior cerebral, except the posterior part for 1 inch (2·5 cm.), where all the fibres are supplied by the posterior cerebral artery. The inferior longitudinal bundle has the same arterial distribution as the optic radiations.

The supply to the different parts of the Corpus callosum, and especially of its posterior constituents, has been exactly determined, and also that of the Uncus and the Cornu ammonis. The direction of the flow of blood in the posterior communicating artery has been found by experiment to be from the carotid to the posterior cerebral artery.

The exact areas of distribution of the Anterior, Middle, and Posterior cerebral arteries to the Centrum ovale, as they appear in sagittal and horizontal sections, are given on Plates 1–7, I believe for the first time.

The present uncertainty about the distribution of the arteries to the cortex is well shown in the case of the anterior cerebral artery. According to DURET, the area of supply extends posteriorly to the fissure of ROLANDO, and, according to QUAIN'S 'Anatomy' (10th edition) and CUNNINGHAM'S 'Text-book of Anatomy,' it extends to the external parieto-occipital fissure. Reference to p. 31 in this paper shows that the most frequent distribution is midway between these two points.

At the present time there is no work which gives a description of the arterial supply to all parts of the brain. It is considered that this can only be accurately ascertained by simultaneous injection of the five arteries with soluble colours, and by employing a large number of cases, as has been done in the present work.

The accurate knowledge of the area of supply of any particular artery is not only of importance from the point of view of anatomy, but it is also of great value from the pathological side, as it is necessary to know, for the purposes of diagnosing disease, the exact portion of the brain which is liable to undergo softening when any particular artery is blocked by a clot of blood.

In conclusion, I desire to state that the injections were carried out in the Pathological Department of the Great Northern Central Hospital, and I would here thank the pathologists of that institution for their help in obtaining material. My special thanks are due to Mr. SKINNER, the dispenser to the hospital, for his valuable help in suggesting various colours, and in preparing the injection masses, as without his assistance the above results would not have been attained.

Parts supplied by the Different Arteries.

Internal Carotid.

Posterior communicating—

Chiasma optica. Tuber cinereum.
Regio subthalamica.
Pes pedunculi, ant. $\frac{1}{3}$.
Capsula interna / Posterior division } ant. $\frac{1}{5}$ or $\frac{1}{3}$.
Thalamus opticus, nucleus externus (anterior external part).
Thalamus opticus, nucleus internus, anterior $\frac{1}{2}$ (sometimes).

Anterior Choroid Artery—

Basal. Tractus opticus.
Pes pedunculi, ant. $\frac{1}{3}$ (sometimes); postero-external $\frac{2}{3}$ (sometimes).
Capsula interna, posterior division, posterior $\frac{4}{5}$ or $\frac{2}{3}$.
Retro-lenticular fibres, posterior to capsula interna, optic radiations at origin.
Surcingle or Tail of Nucleus caudatus.
Nucleus lenticularis, external segment, posterior inferior part (sometimes).
Nucleus lenticularis, internal segment.
Choroid plexus, in descending and posterior cornua.
Choroid membrane, in cornu descendens, anterior to posterior surface of crus.
Nucleus amygdalæ.
Commissura anterior (extreme outer part).
Cortical. Uncinate gyrus.

Anterior Cerebral—

Basal. Lamina terminalis vel Cinerea (floor of third ventricle).
Capsula interna, anterior division, inferior $\frac{1}{2}$.
Caput nuclei caudati, inferior $\frac{1}{2}$.
Nucleus lenticularis, external segment (anterior inferior parts).
Nucleus lenticularis, middle segment (anterior inferior part).
Columna anterior fornicis (superior part).
Septum lucidum.
Commissura anterior, median part.
Cortical. Gyrus rectus orbitalis, inferior surface.
Gyrus fornicatus / Gyrus marginalis / Lobulus quadratus, ant. $\frac{3}{4}$ } median surface.

Corpus Callosum.
Gyrus frontalis superior
Gyrus frontalis ascendens } superior $\frac{1}{4}$
Gyrus parietalis ascendens
Gyrus parietalis superior (anterior $\frac{1}{2}$)
} external surface.

Middle Cerebral—

Basal. Capsula interna, anterior division, superior $\frac{1}{2}$.
Capsula interna, posterior division, above level of middle segment of lenticular nucleus.
Caput nuclei caudati, superior $\frac{1}{2}$.
Nucleus caudatus, horizontal part
Nucleus lenticularis, external segment (all in $\frac{1}{2}$ cases).
Nucleus lenticularis, middle segment (all, except anterior inferior part sometimes).
Commissura anterior (outer part).

Cortical. Gyri orbitales internus medius et externus.
Gyrus frontalis ascendens, inferior $\frac{3}{4}$.
Gyrus parietalis ascendens, inferior $\frac{3}{4}$.
Gyrus parietalis superior (sometimes, posterior $\frac{1}{2}$).
Gyrus supra-marginalis.
Gyrus angularis.
Gyrus temporalis superior.
Gyrus temporalis medius.
Gyrus temporalis inferior (superior $\frac{1}{2}$ sometimes).
Anterior end of lobus temporalis.

Basilar Artery.

Posterior Cerebral Artery—

Basal. Corpus mammillare.
Pes pedunculi, posterior $\frac{2}{3}$.
Nucleus ruber.
Thalamus opticus, posterior $\frac{1}{2}$.
Thalamus opticus, nucleus anterior.
Thalamus opticus, nucleus externus (anterior superior part).
Thalamus opticus, nucleus externus, posterior $\frac{1}{2}$.
Thalamus opticus, nucleus internus, posterior $\frac{1}{3}$.
Choroid plexus in ventricularis lateralis centralis.
Choroid membrane (in cornu descendens, posterior to posterior surface of crus, and in ventricularis lateralis centralis).
Corpus geniculatum internum.

Corpus geniculatum externum.
Corpus fornicis.
Columna descendens fornicis, inferior part.
Crus posterior fornicis.

Cortical. Gyrus temporalis inferior, inferior $\frac{1}{2}$.

Gyrus fusiformis.
Gyrus lingualis.
Gyrus cuneus.
Gyrus quadratus, posterior $\frac{1}{2}$ inch.
} median surface.

DESCRIPTION OF PLATES 1–8.

Plates 1–7 are photographs of the original sections, reproduced by the chromo-collotype process. In all the figures the area, where injected, of each artery is of the same colour, viz. :—

Posterior communicating artery . . .	Brown.
Anterior choroid artery	Yellow.
Anterior cerebral artery	Green.
Middle cerebral artery	Carmine.
Posterior cerebral artery	Blue.

Plate 1.

Figs. 1 and 2.—Sagittal sections of the human brain made $\frac{3}{8}$ inch (1 cm.) and $\frac{9}{16}$ inch (1·5 cm.), respectively from the median surface of the left hemisphere. The three arteries, anterior, middle, and posterior cerebral were injected at the same time, the posterior communicating artery was ligatured at each end, and the anterior choroid artery was ligatured at its origin (Class D, pp. 13, 14), so that the areas supplied by these two arteries are not injected, and appear white.

Plate 2.

Figs. 3 and 4.—Horizontal sections of the human brain made through the most superior part of the optic thalamus, and of the lenticular nucleus respectively. Four arteries, the anterior, middle, and posterior cerebrals and the anterior choroid were injected simultaneously, and the posterior communicating artery was ligatured at each end (Class E) and the area supplied by it is not injected.

Plate 3.

Figs. 5 and 6.—Horizontal sections of the same brain made through the most superior part of the internal segment of the lenticular nucleus, and of the anterior commissure respectively. The arteries are injected as in Plate 2.

PLATE 4.

Figs. 7 and 8.—Horizontal sections of the same brain made through the superior part of the corpora quadrigemina, and the nucleus ruber with the corpora geniculata, respectively. The arteries are injected as in Plate 2.

PLATE 5.

Figs. 9 and 10.—Coronal sections of the human brain made through the anterior commissure (superior median part), and just posteriorly to the optic chiasma, respectively. Five arteries, the anterior, middle, and posterior, cerebrals, the anterior choroid, and the posterior communicating arteries were simultaneously injected with different colours (Class G).

PLATE 6.

Figs. 11 and 12.—Coronal sections of the same brain made through the tuber cinereum and the genu of the internal capsule, and through the most anterior part of the pons, respectively. The arteries are injected as in Plate 5.

PLATE 7.

Figs. 13 and 14.—Coronal sections of the same brain made just posteriorly to the lenticular nucleus, and through the posterior part of the optic thalamus, respectively. The arteries are injected as in Plate 5.

Plate 8 shows photographs of the external surface of an injected brain. The vertical shading represents the area supplied by the anterior cerebral artery, the oblique shading that of the middle cerebral artery, the horizontal that of the posterior cerebral artery, and the small rings that of the anterior choroid artery.

PLATE 8.

Figs. 15 and 16 show the external and median surfaces of a brain in which the anterior, middle, and posterior cerebral arteries were separately injected.

Figs. 17 and 18 show the superior and inferior surfaces of the same brain. In figs. 15 and 17, the posterior cerebral area extends beyond the external parieto-occipital fissure for half way along the parietal lobule, so as to join the anterior cerebral area and so prevent the middle cerebral area from reaching the median line, as commonly occurs (see fig. 5, p. 33).

N.B.—The small ringed areas in figs. 16 and 18 were filled in from another brain where the anterior choroid artery was also injected.

EXPLANATION OF LETTERING TO THE PLATES.

(The same letters apply to all the figures.)

A. l.	Ansa lenticularis.				
C.	Cuneus.				
C. A.	Calcar Avis.				
C. a.	Commissura anterior.				
Calc.	Fissura Calcarina.				
Call. Marg.	Calloso-Marginal sulcus.				
C. Am.	Cornu Ammonis.				
C. C.	Corpus Callosum.				
C. C. f. m.	,,	,,	forceps major.		
C. C. g.	,,	,,	genu.		
C. E.	Capsula externa.				
Cer.	Cerebellum.				
C. g. e.	Corpus geniculatum externum.				
C. g. i.	,,	,,	internum.		
Ch.	Chiasma of optic nerves.				
C. I. a.	Capsula Interna, anterior segment.				
C. I. g.	,,	,,	genu.		
C. I. p.	,,	,,	posterior segment.		
C. I. p. s.	,,	,,	,,	,,	superior part.
C. I. p. i.	,,	,,	,,	,,	inferior part.
Cl.	Claustrum.				
C. m.	Commissura mollis.				
C. O.	Centrum ovale.				
Coll.	Fissura Collateralis.				
C. p.	Commissura posterior.				
C. q. a.	Corpus quadrigeminum anterius.				
C. R.	Corona Radiata.				
Cr.	Crusta or Pes pedunculi.				
C. S.	Corpus Subthalamicum (LUY's body).				
F.	Fornix.				
F. ant.	,,	anterior pillar.			
F. p.	,,	posterior pillar.			
F. 1.	Gyrus Frontalis Superior.				
F. 2.	,,	,,	Medius.		
F. 3.	,,	,,	Inferior.		
f. 1.	Sulcus frontalis superior.				
f. 2.	,,	,,	inferior.		

F. a.	Gyrus frontalis ascendens.
F. D.	Fascia Dentata.
F. D. a.	,, ,, anterior end.
F. H.	Fissura Hippocampi.
Fi.	Fimbria.
F. l. i.	Fasciculus longitudinalis inferior.
F. M.	Foramen of Monro.
F. R.	Fissura Rolandi.
F. S.	Fissura Sylvii.
Fus.	Gyrus fusiformis.
G. H.	Gyrus Hippocampi.
G. Hab.	Ganglion Habenulæ of optic thalamus.
I.	Iter a tertio ad quartum ventriculum.
I. P. s.	Intra-parietal sulcus.
L.	Gyrus Lingualis.
L. c. a.	Lenticulo-caudate arteries from middle cerebral arteries.
L. m. e.	Lamina medullaris externa of optic thalamus.
L. N.	Locus niger.
L. p. a.	Locus perforatus anticus.
Mid. C.	Middle Cerebral artery branches.
N. A.	Nucleus Amygdalæ.
N. C.	Nucleus Caudatus.
N′. C′.	Nucleus Caudatus, Tail or Surcingle.
N. C. c.	,, ,, Caput.
N. C. h.	,, ,, horizontal part.
N. L. 1.	Nucleus Lenticularis, Internal segment.
N. L. 2.	,, ,, Middle segment.
N. L. 3.	,, ,, External segment.
N. R.	Nucleus Ruber.
O. R.	Optic Radiations.
P.	Pons Varolii.
P. a.	Gyrus parietalis ascendens.
p. c. s.	Præcentral sulcus.
P. Ch. l.	Plexus choroideus lateralis.
P. Ch. p.	,, ,, posterior (posterior cornu).
P. O.	Fissura parieto-occipitalis.
p. s.	Parallel or first temporal sulcus.
Pulv.	Pulvinar Thalami optici.
Qu.	Lobulus quadratus.
R. l.	Retro-lenticular fibres.
R. S.	Regio Subthalamica.

S. g. c.	Substantia grisea centralis.
S. L.	Septum Lucidum.
S. M.	Gyrus supra-marginalis.
Spl.	Splenium Corporis Callosi.
T. 1.	Gyrus Temporalis Superior
T 2.	,, ,, Medius.
T. 3.	,, ,, Inferior.
t. 2.	Second Temporal sulcus.
t. 3.	Third ,, ,,
Tap.	Tapetum Corporis Callosi.
T. c.	Tuber cinereum.
Th.	Thalamus opticus.
Th. n. a.	,, ,, nucleus anterior.
Th. n. e.	,, ,, ,, externus.
Th. n. i.	,, ,, ,, internus
T. O.	Tractus Opticus.
U	Uncus.
U′.	Root of uncus, where it is joined by fascia dentata.
V. iii.	Ventriculus Tertius.
V. G.	Vena Galeni.
Vicq.	Tract of Vicq. d'Azyr.
V. L.	Ventriculus Lateralis.
V. L. c. a.	,, ,, cornu anterius.
V. L. c. d.	,, ,, ,, descendens.
V. L. c. p.	,, ,, ,, posterius.
V. s. l.	Ventriculus Septi lucidi.

Fig. 1.

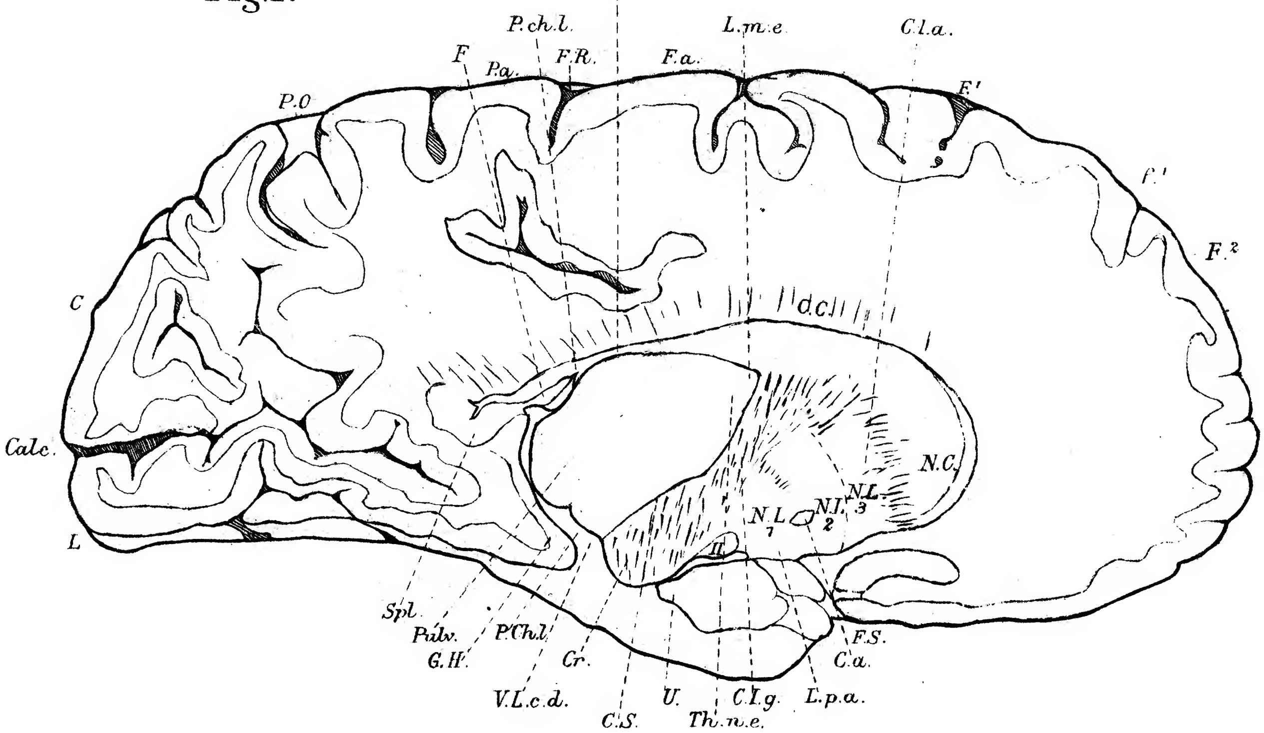

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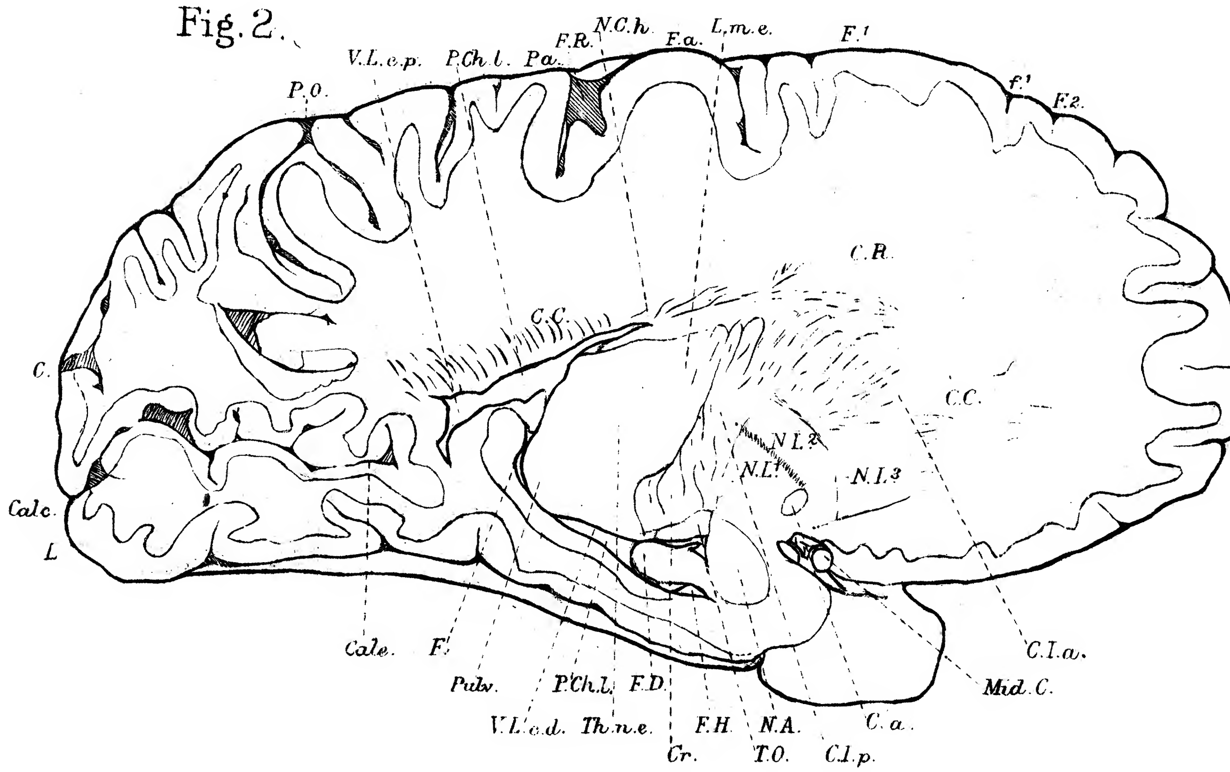
Fig. 2.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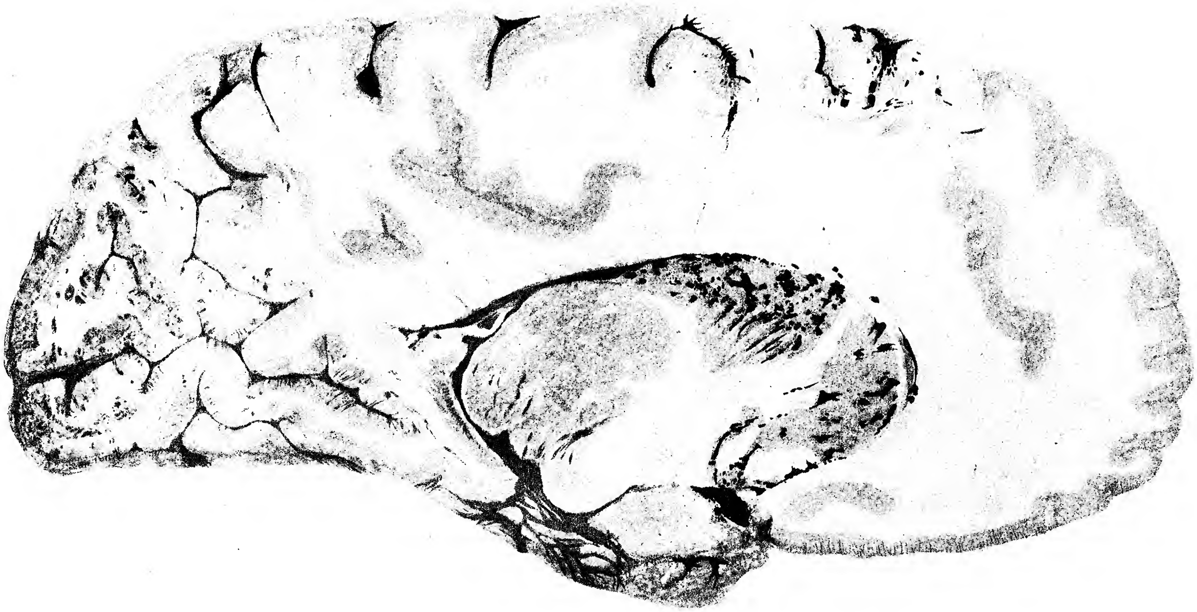

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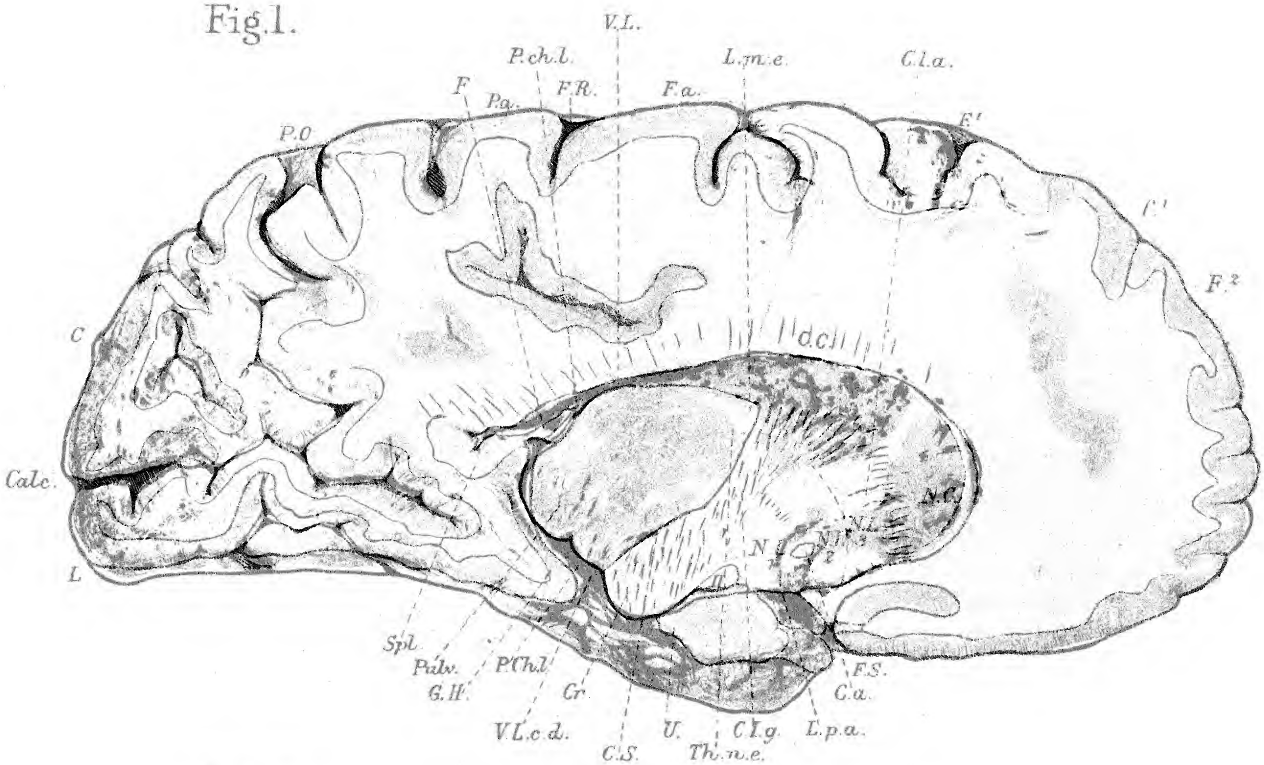
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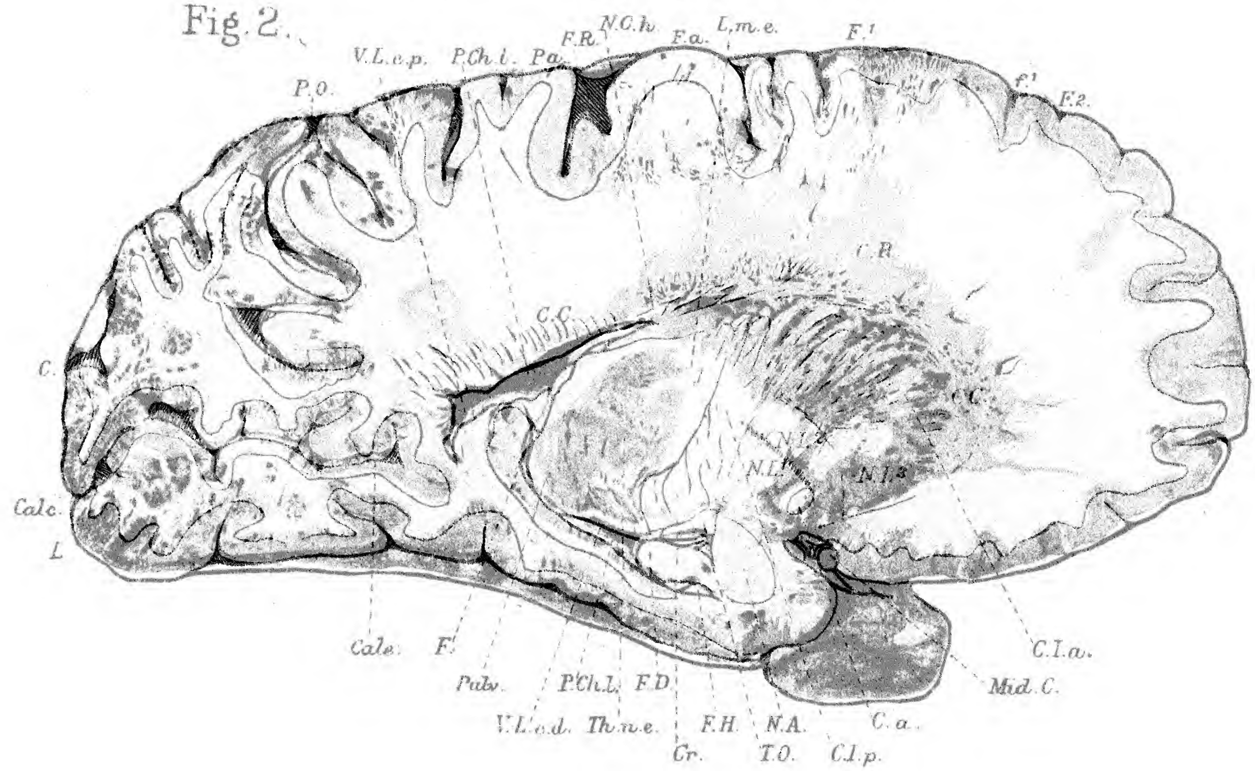
Fig. 2.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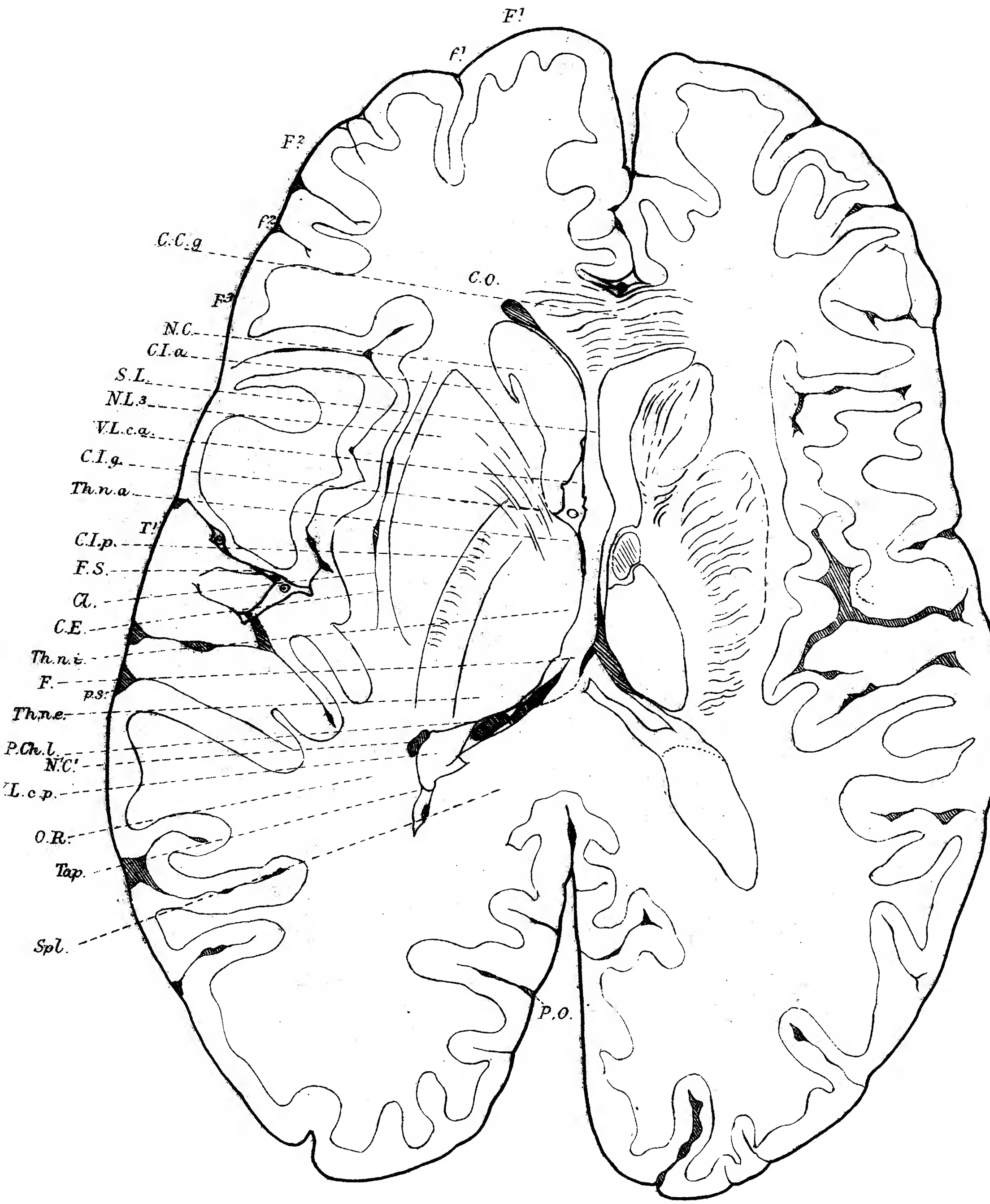
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Fig. 4.

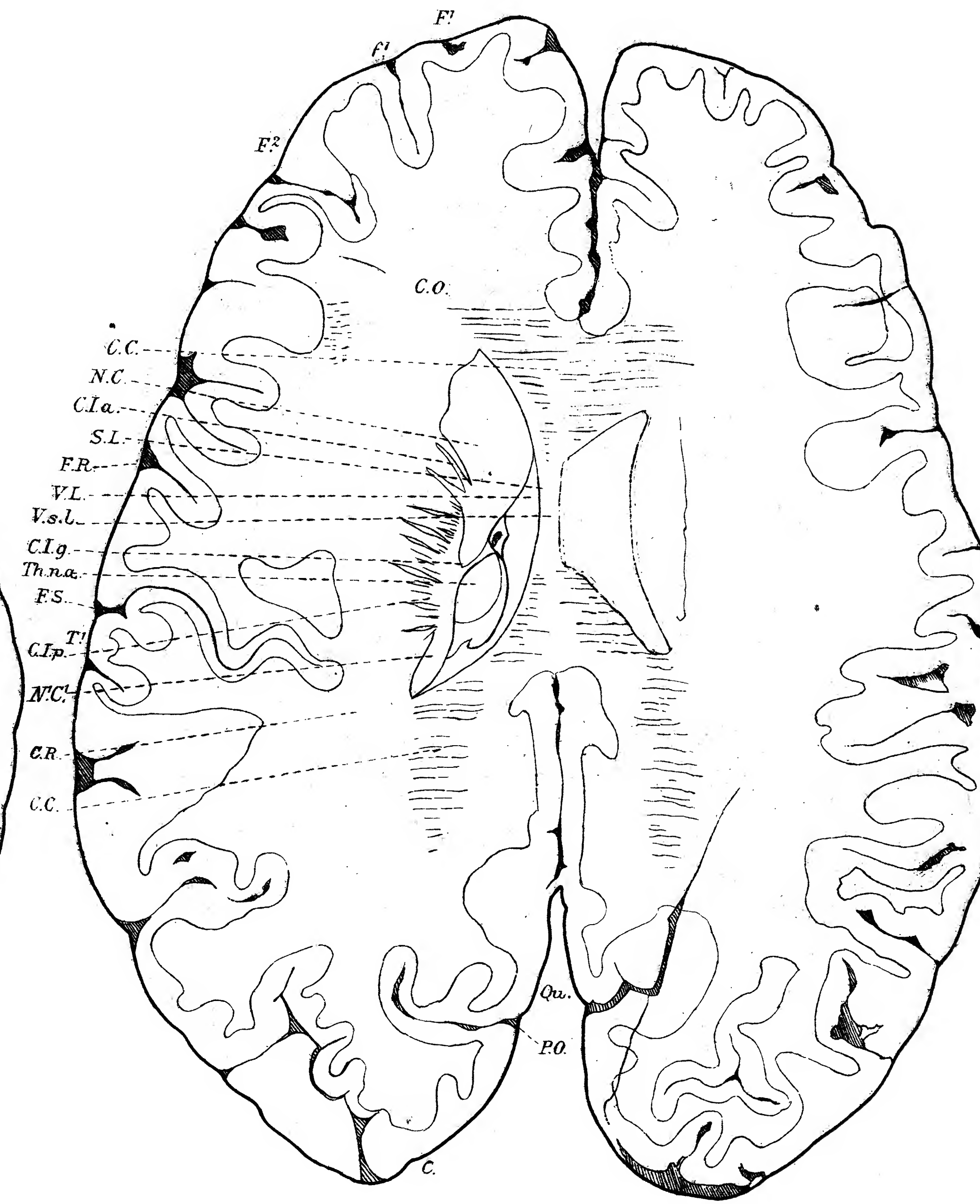
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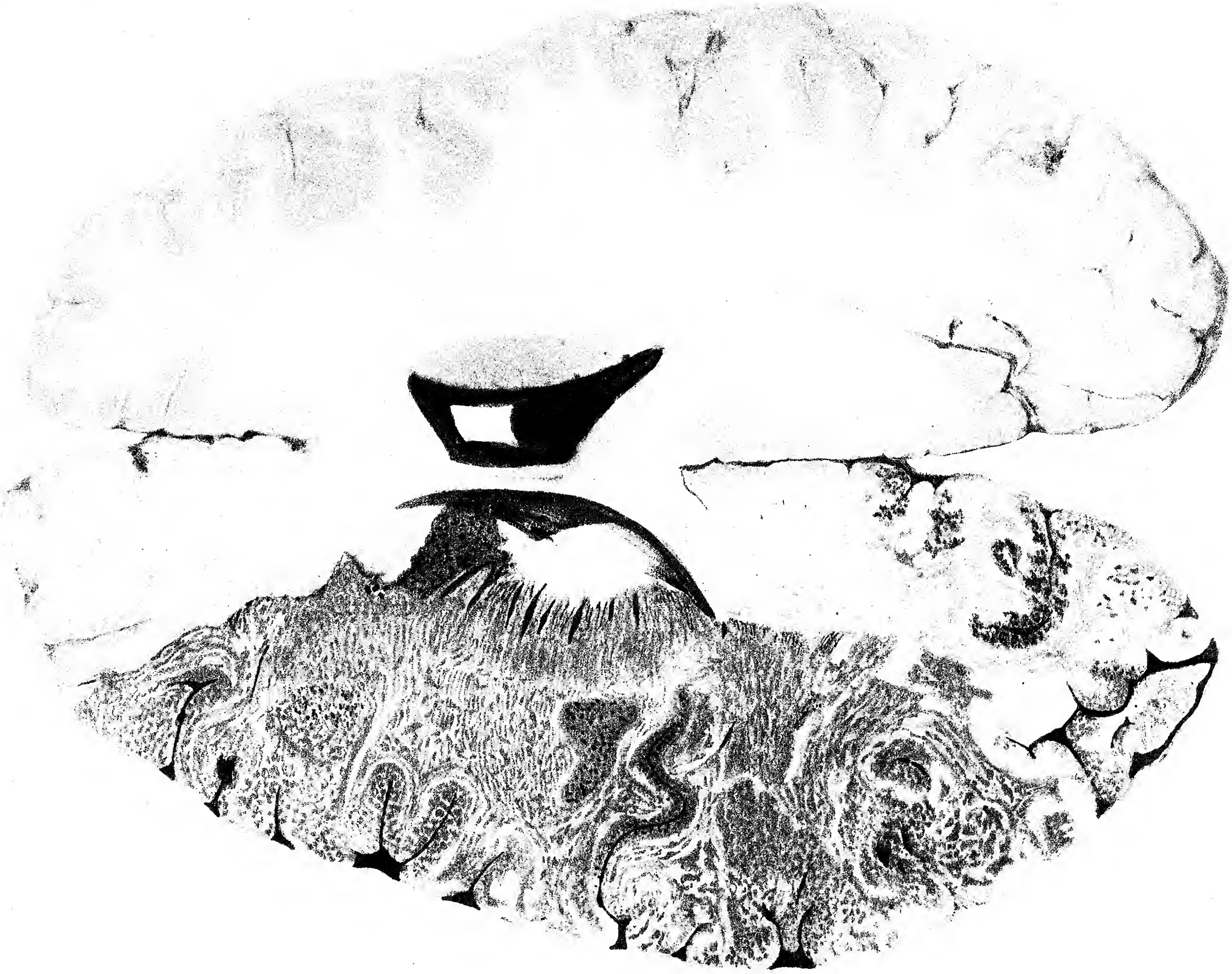
Fig. 3.



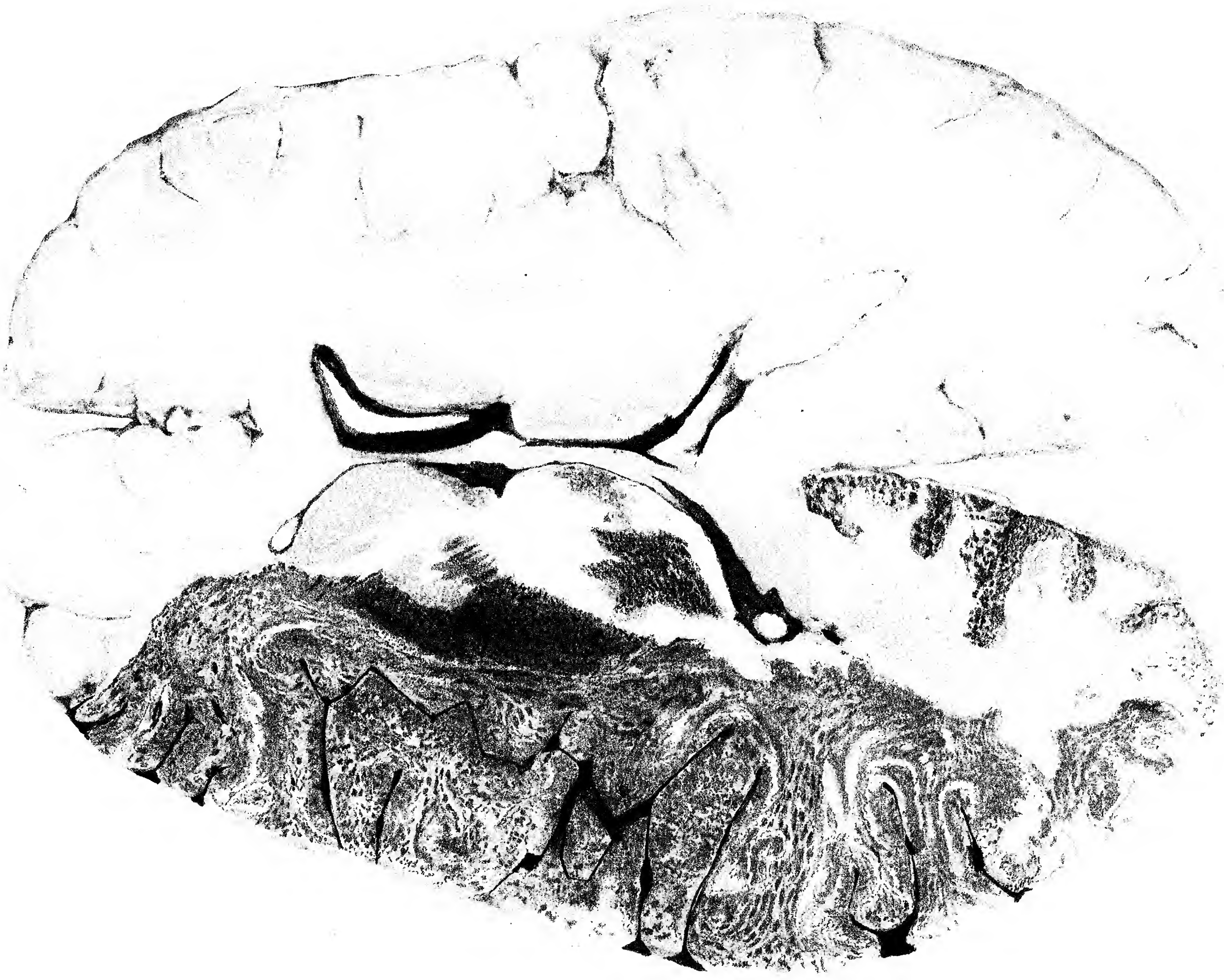



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Fig. 4.

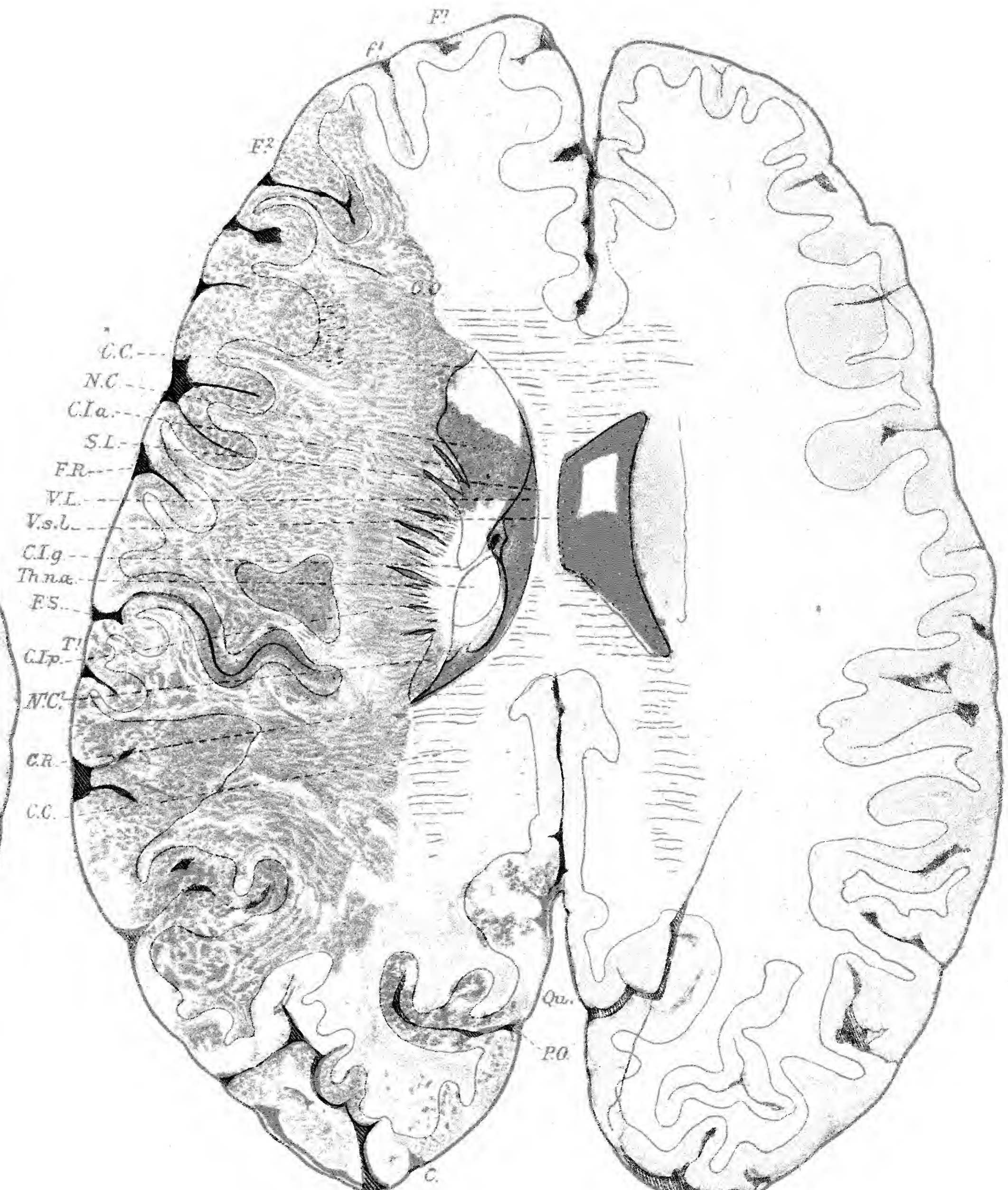
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Fig. 3.

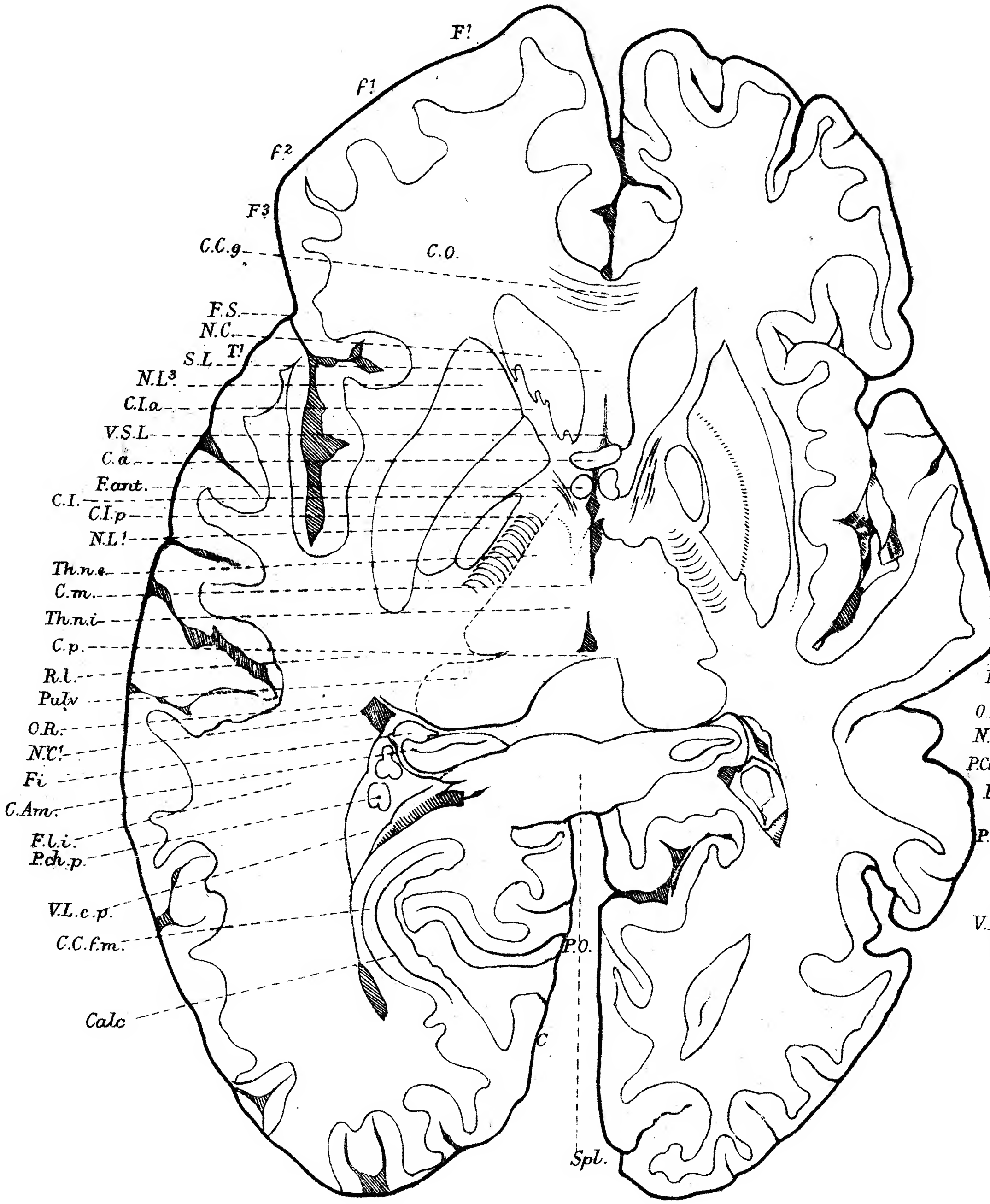
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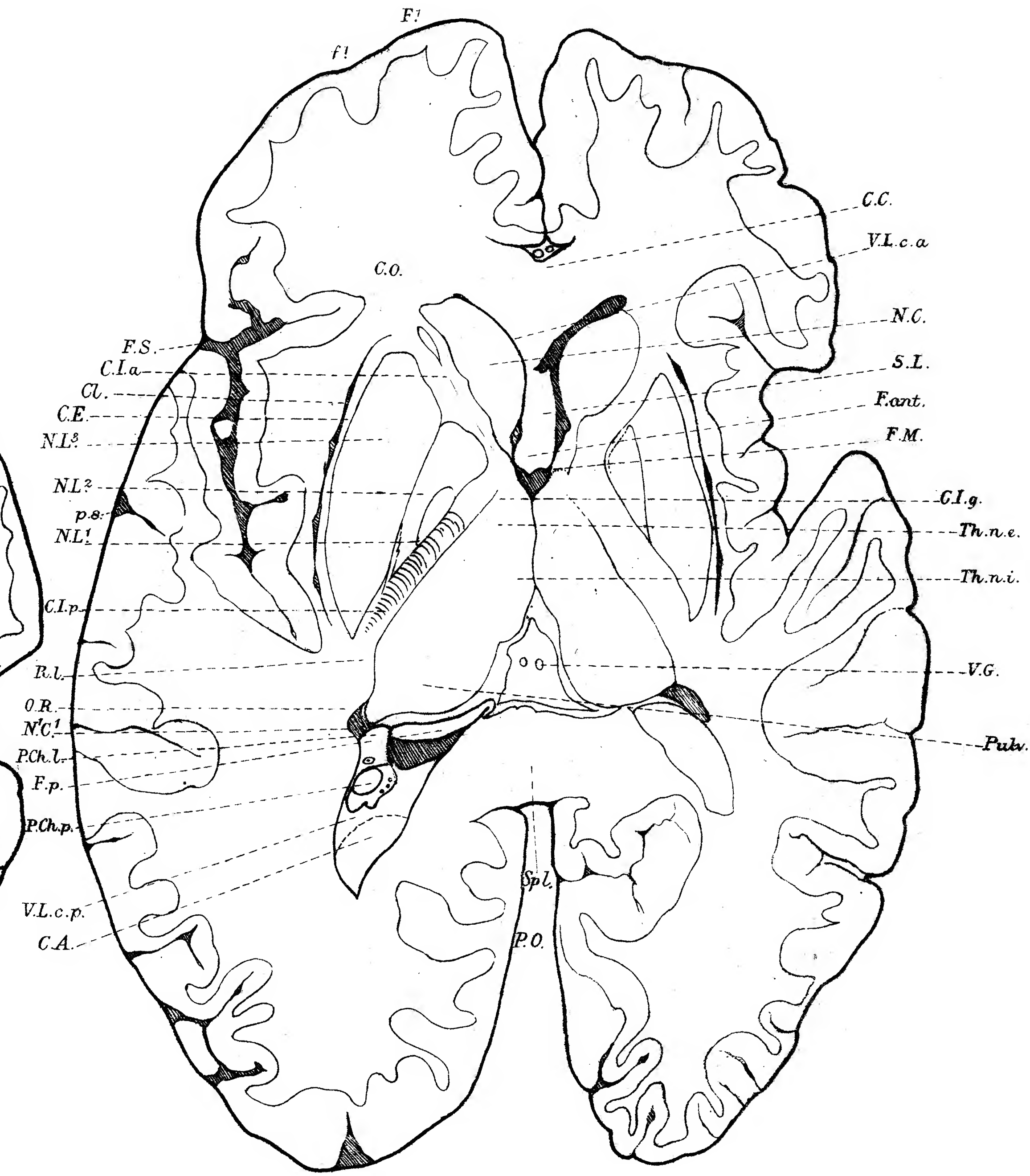
Fig. 6.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V.G.
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N.C.1
P.Ch.l.
F.p.
P.Ch.p.
Pulv.
V.L.c.p.
C.A.
Spl.
P.O.
Fig. 5.


F¹
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C.C.g.
C.O.
F.S.
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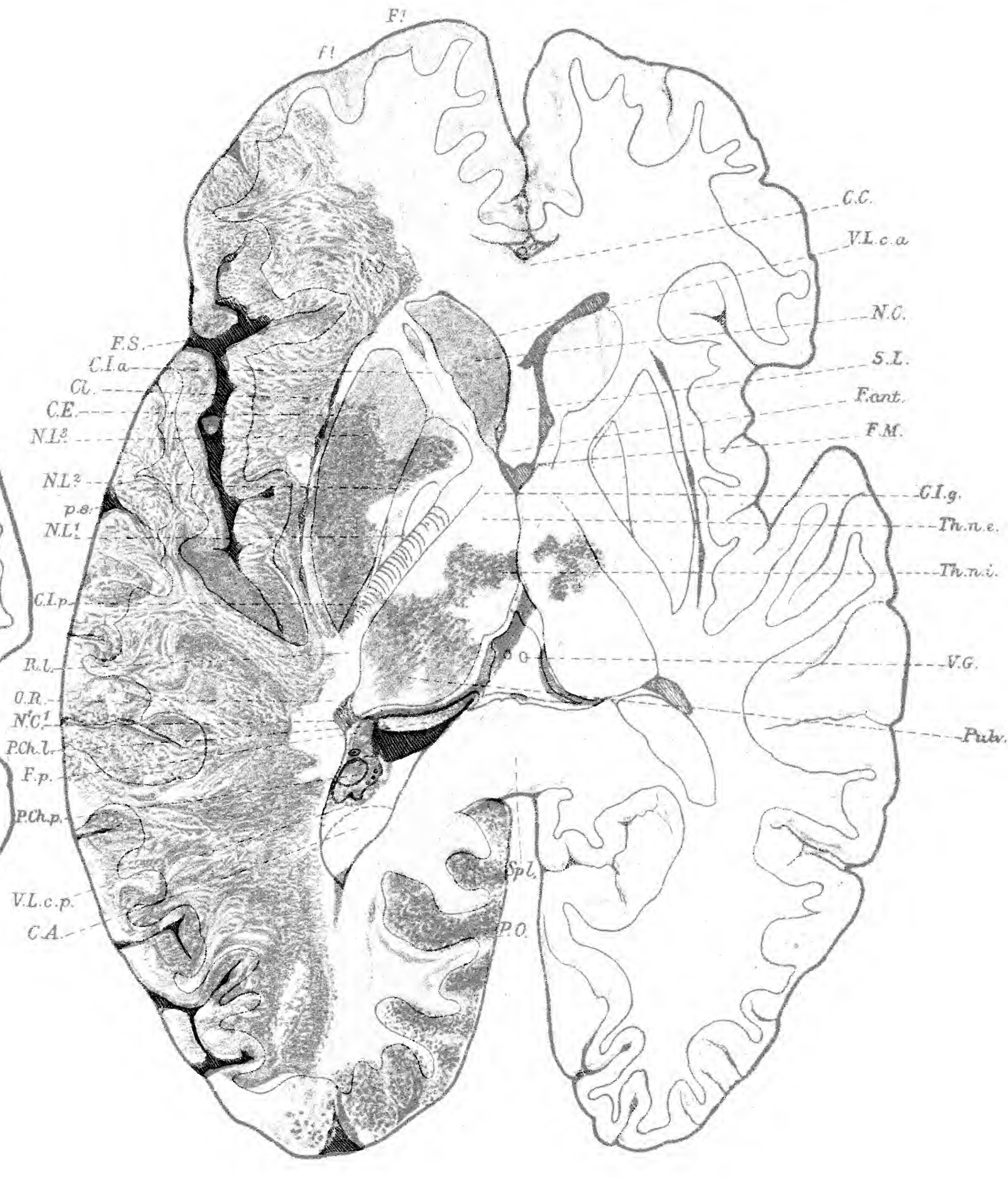
T¹
S.L.
N.L³
C.I.a.
V.S.L.
C.a.
F.ant.
C.I.
C.I.p.
N.L¹
Th.n.e.
C.m.
Th.n.i.
C.p.
R.l.
Pulv.
O.R.
N.C¹
Fi.
C.Am.
F.l.i.
P.ch.p.
V.L.c.p.
C.C.f.m.
Calc.
P.O.
Spl.

Fig. 6.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Th.n.i.
V.G.
Pulv.
F.S.
C.I.a.
Cl.
C.E.
N.L³
N.L²
p.s.
N.L¹
C.I.p.
R.l.
O.R.
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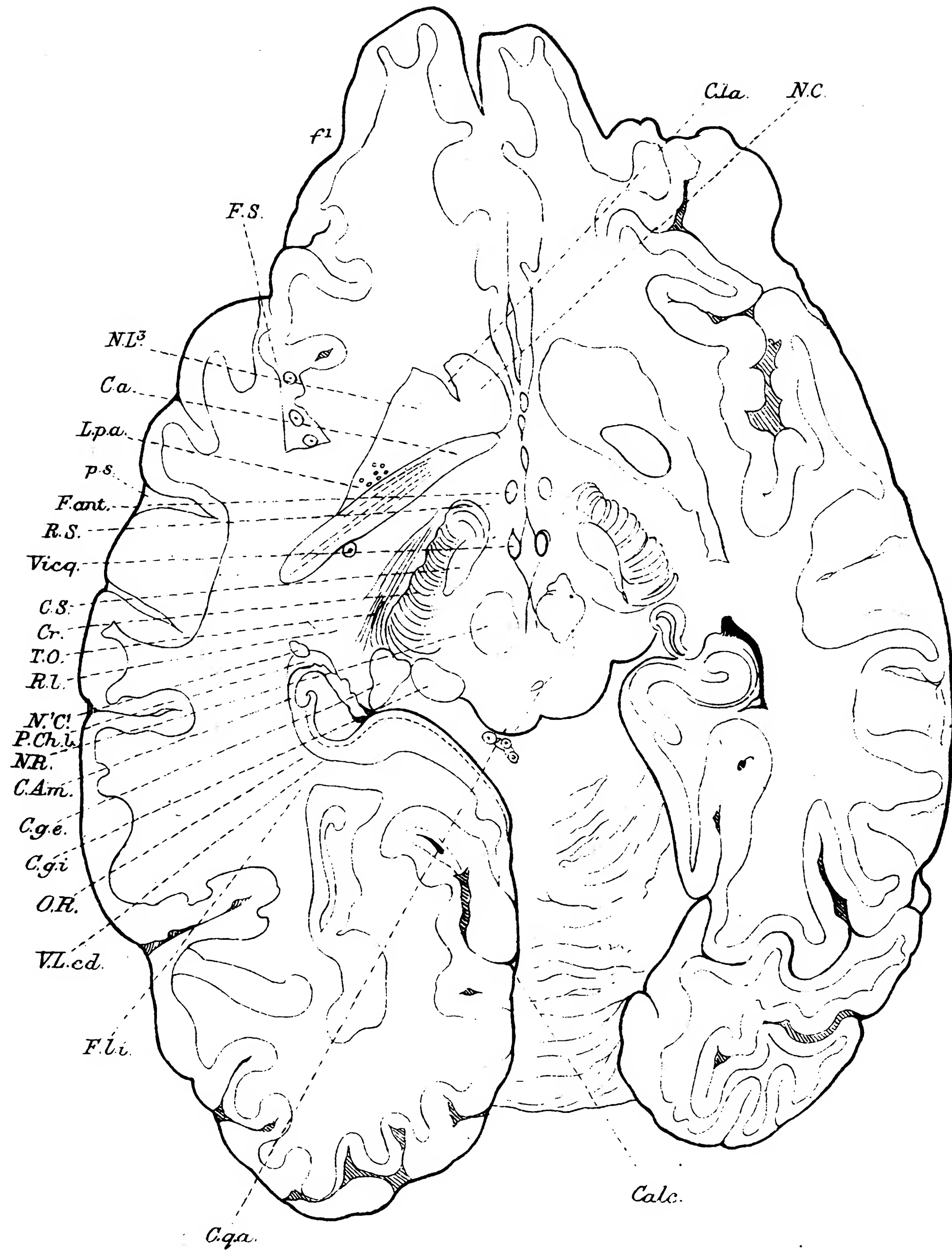
Spl.
P.O.

Fig. 5.



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N.L³
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Vicq.
C.S.
Cr.
T.O.
R.l.
N.'C.¹
P.Ch.l.
N.R.
C.Am.
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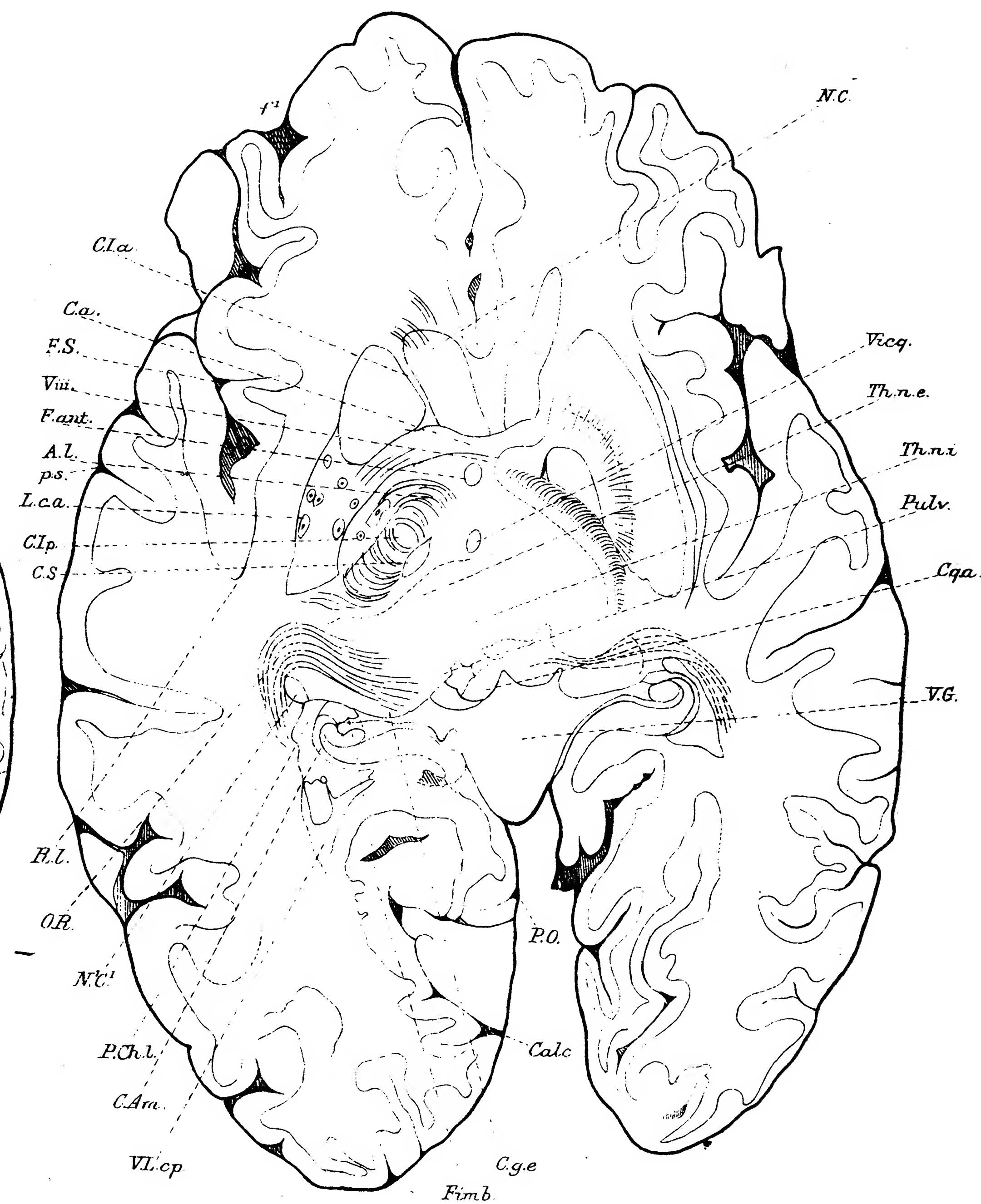
O.R.
V.L.cd.
F.l.i.
C.q.a.
Calc.

Fig. 8.



f¹
N.C.
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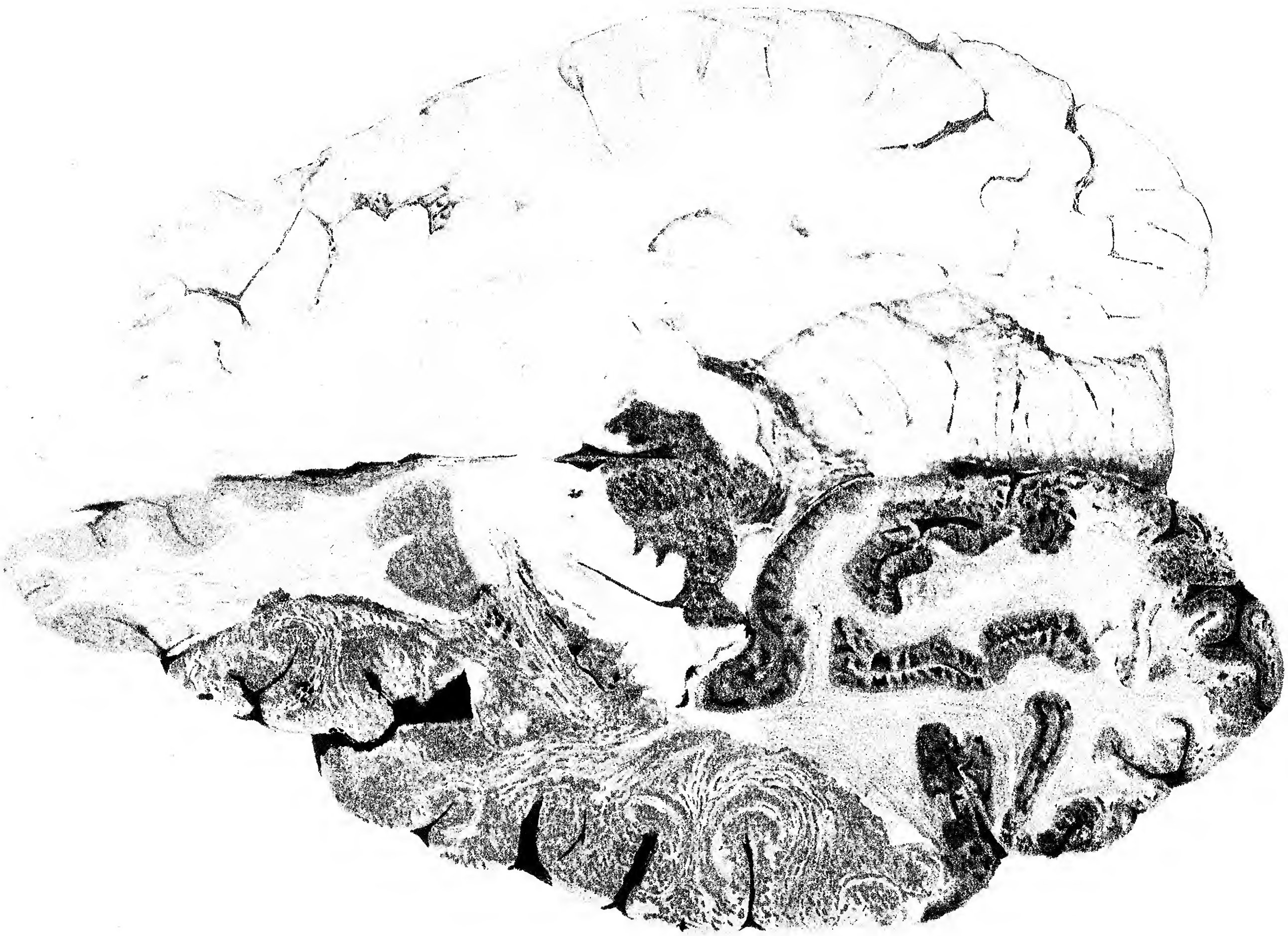
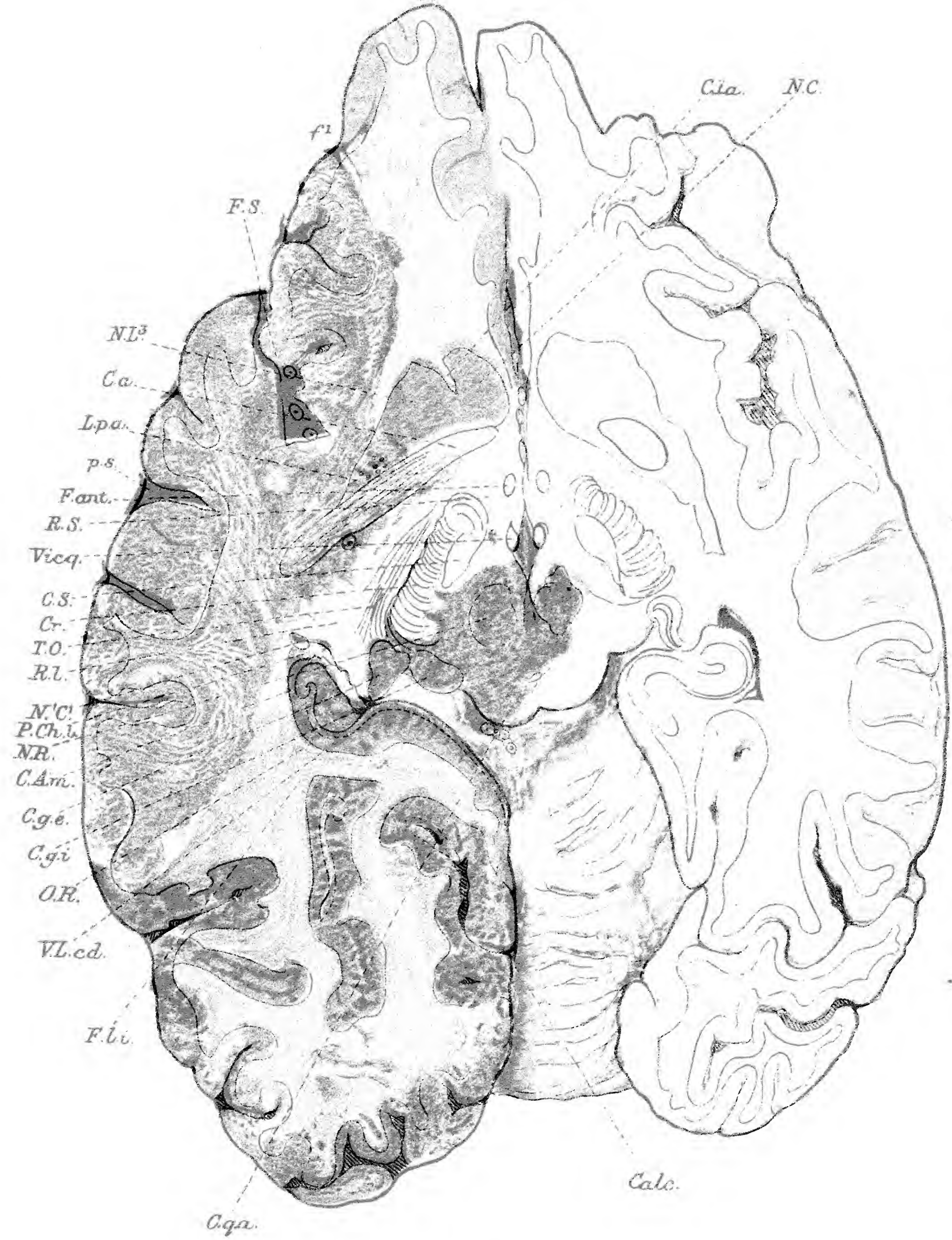
C.a.
F.S.
Viii.
F.ant.
A.l.
p.s.
L.c.a.
C.I.p.
C.S.
Vicq.
Th.n.e.
Th.n.i.
Pulv.
Cqa.
V.G.
R.l.
O.R.
N.'C.¹
P.Ch.l.
C.Am.
VL.cp.
P.O.
Calc.
C.g.e.
Fimb.

Fig. 7.

Phil. Trans. B. vol. 200, Pl. 4.



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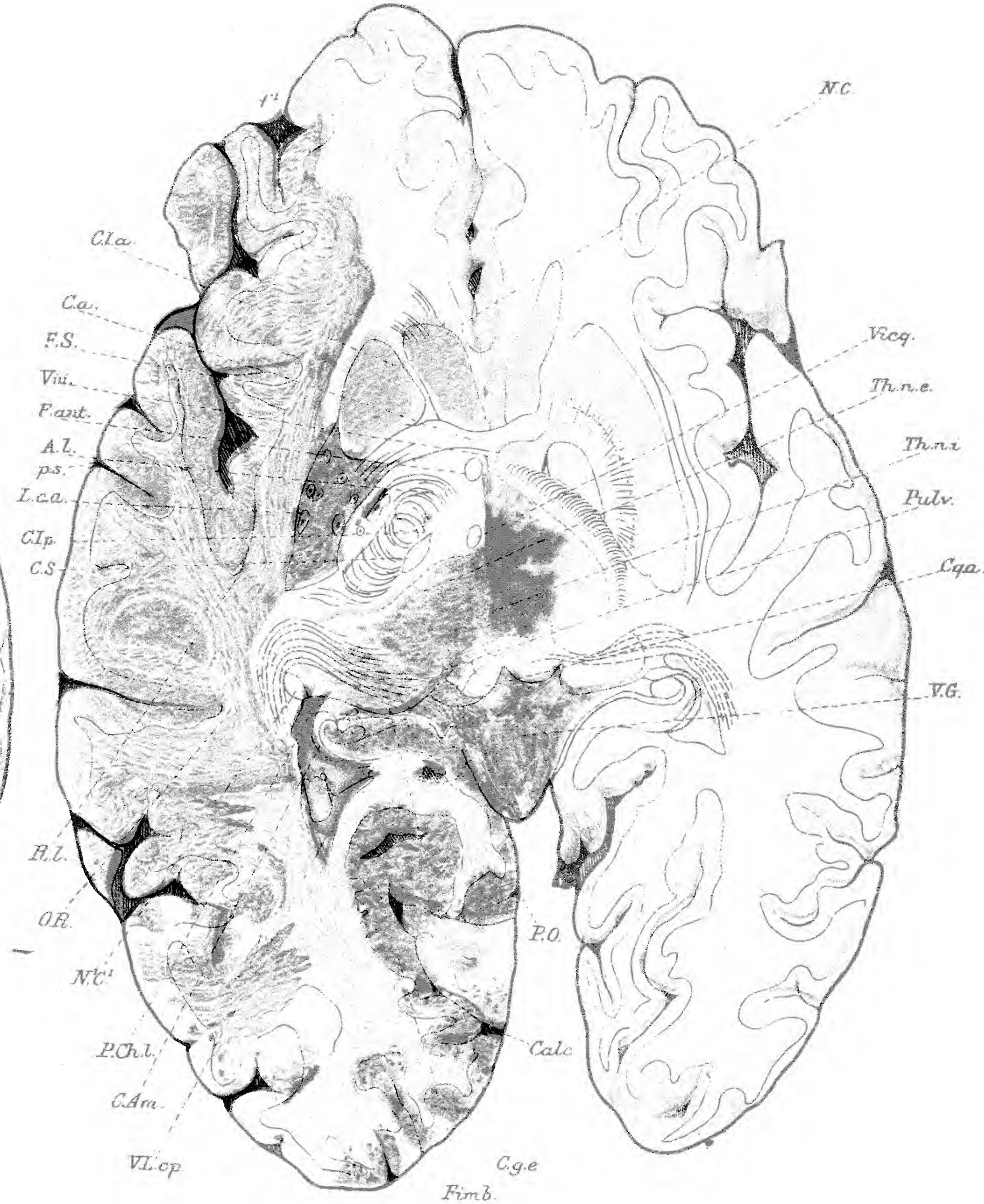
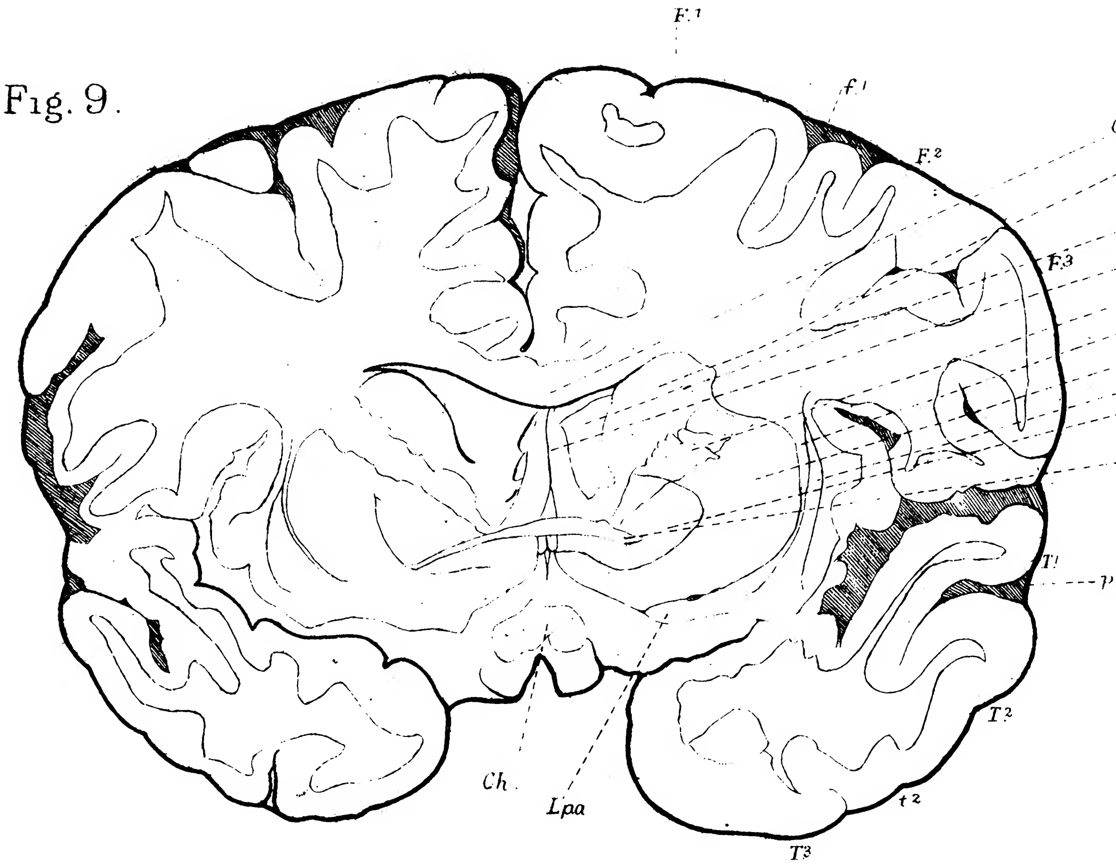


Fig. 7.

Fig. 9.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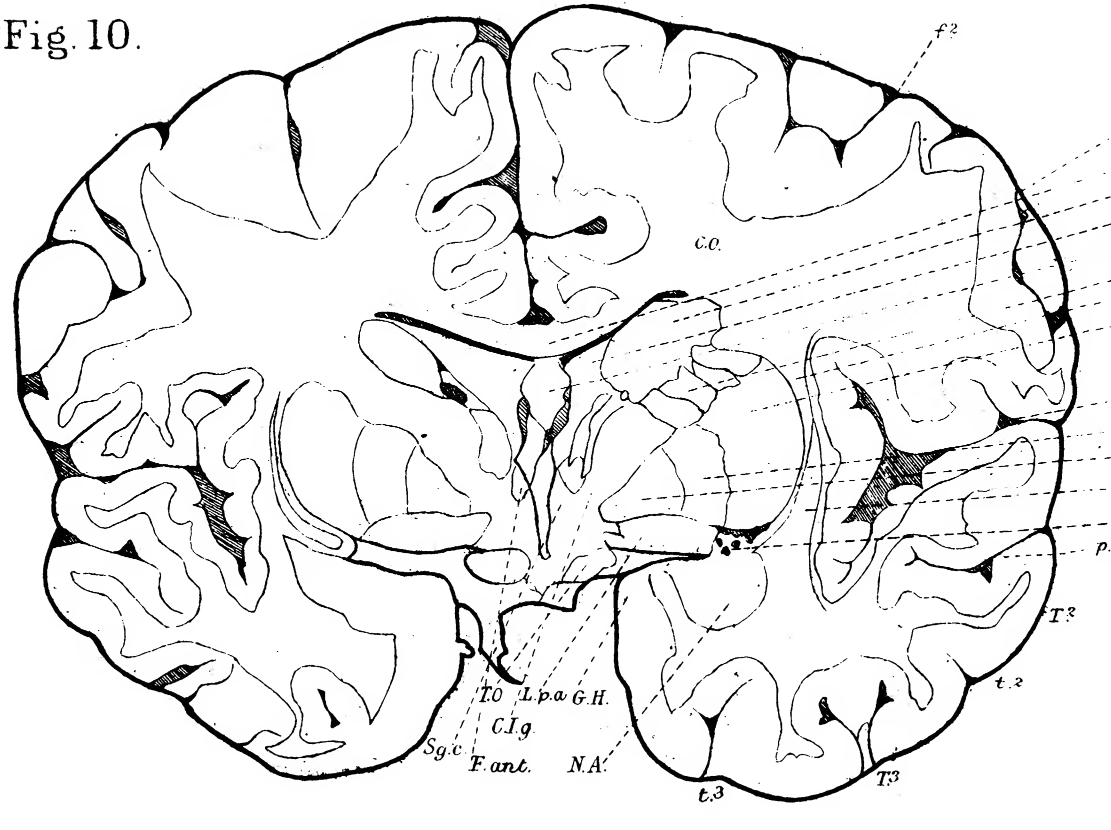
Ca.
T.1
p.s.
T.2
Ch.
L.pa
t.2
T.3

Fig. 10.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F.S.
N.L.2
N.L.1
Cl.
L.c.a.
p.s.
T.2
t.2
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G.H.
C.I.g.
Sg.c.
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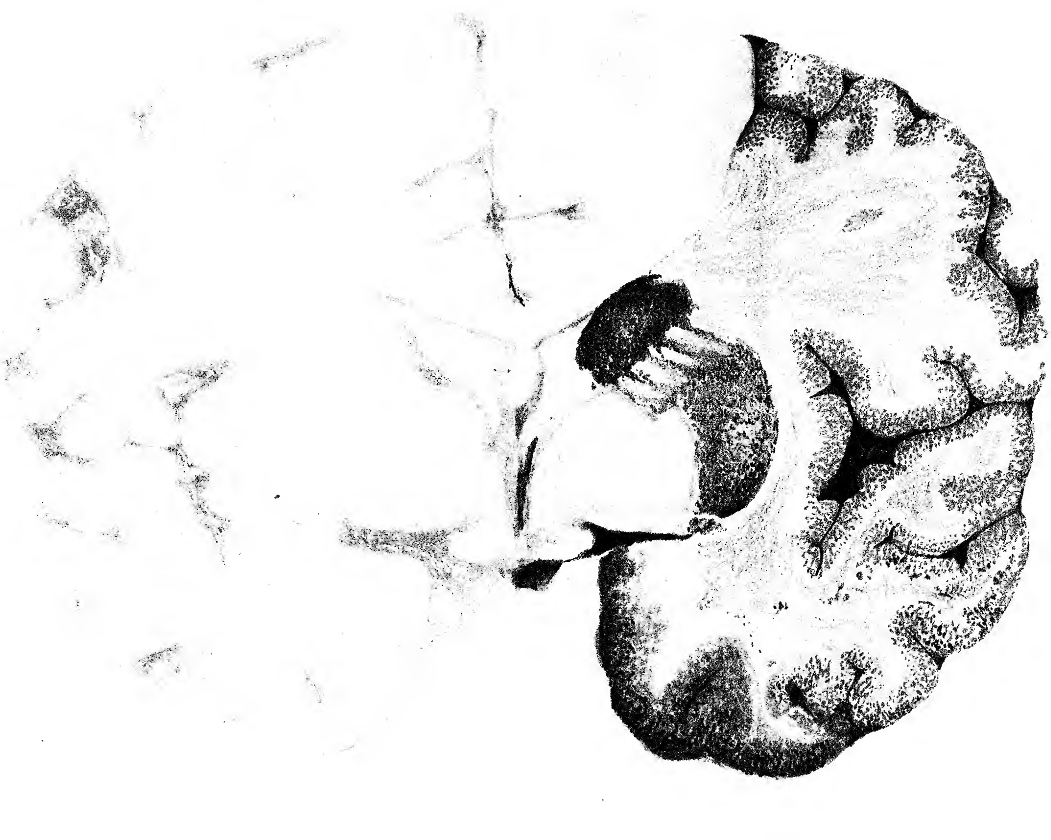
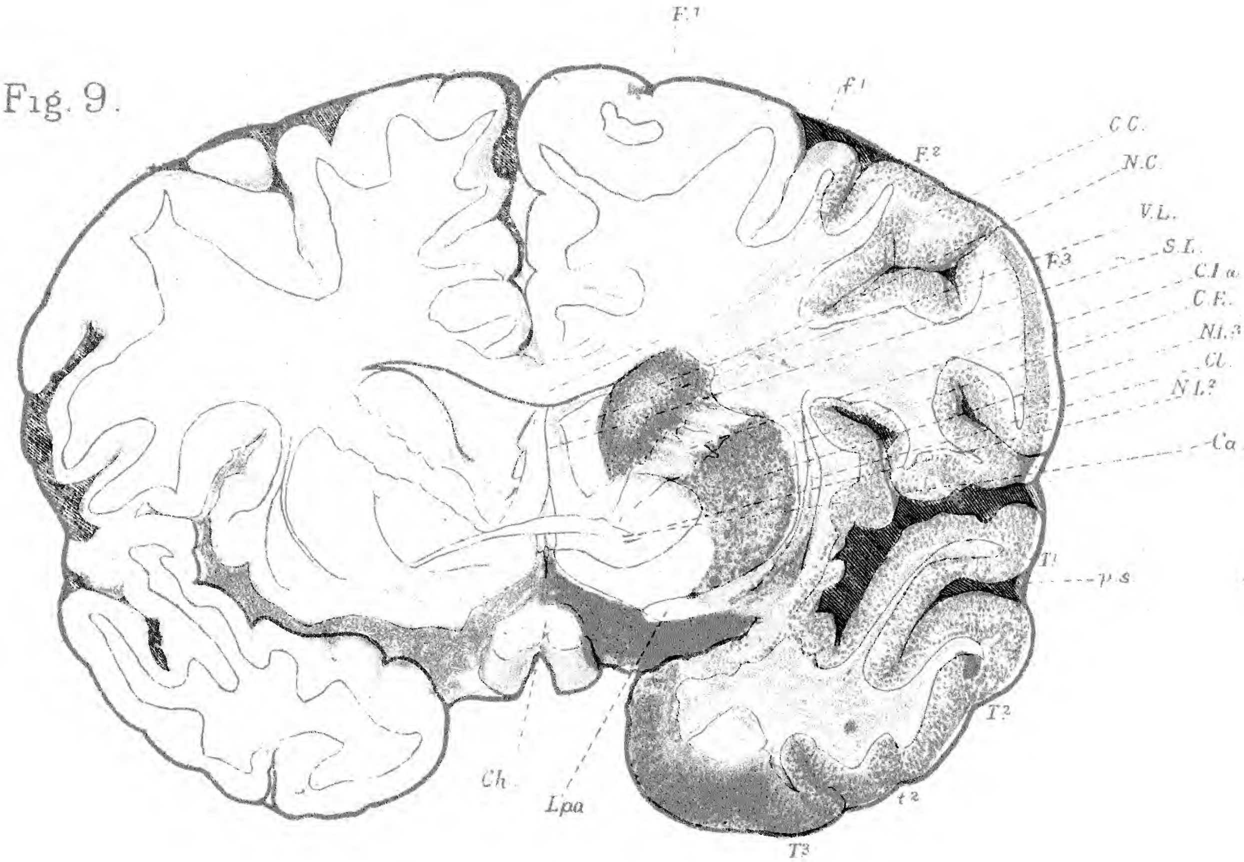
N.A.
t.3
T.3

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T1
p.s.
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t2
T3
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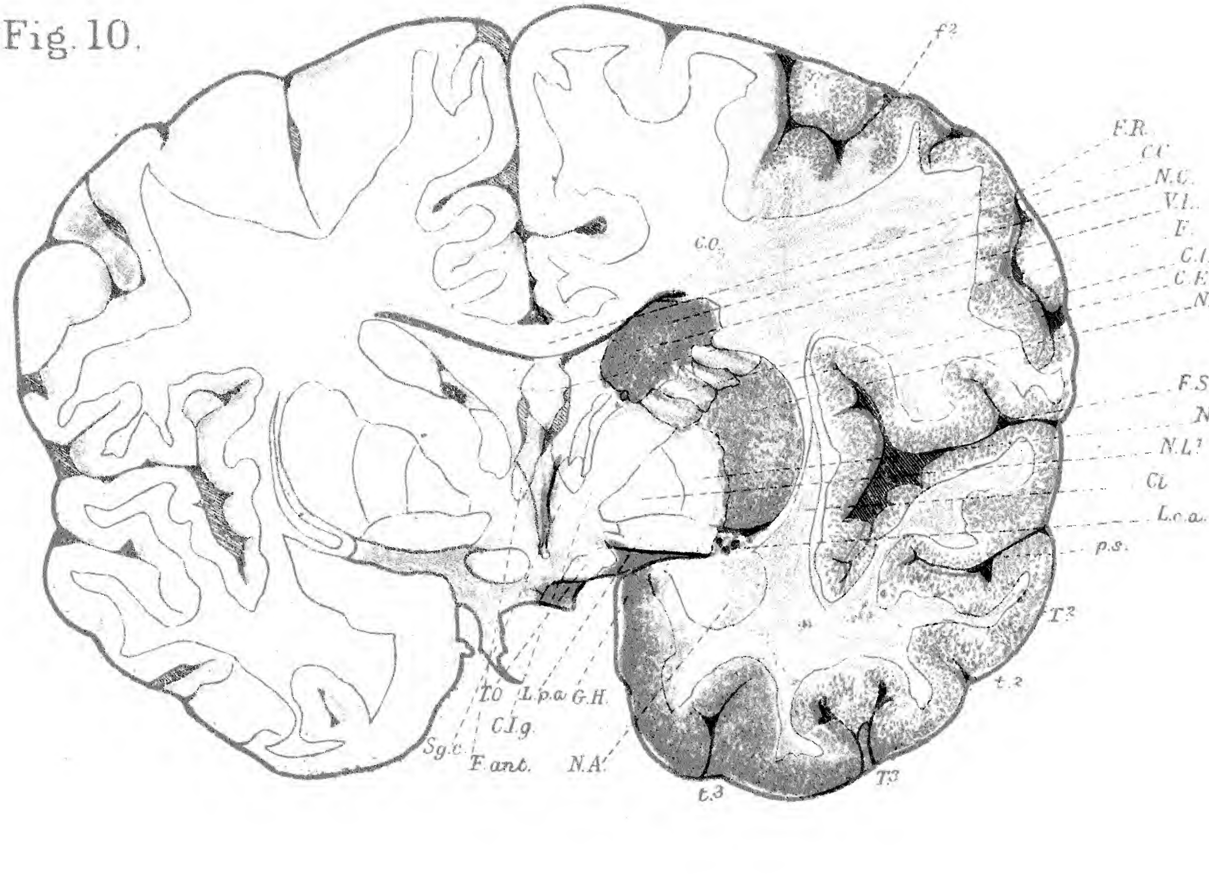
Fig. 9.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N.L.2
N.L.1
Cl.
L.c.a.
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T2
t.2
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t.3
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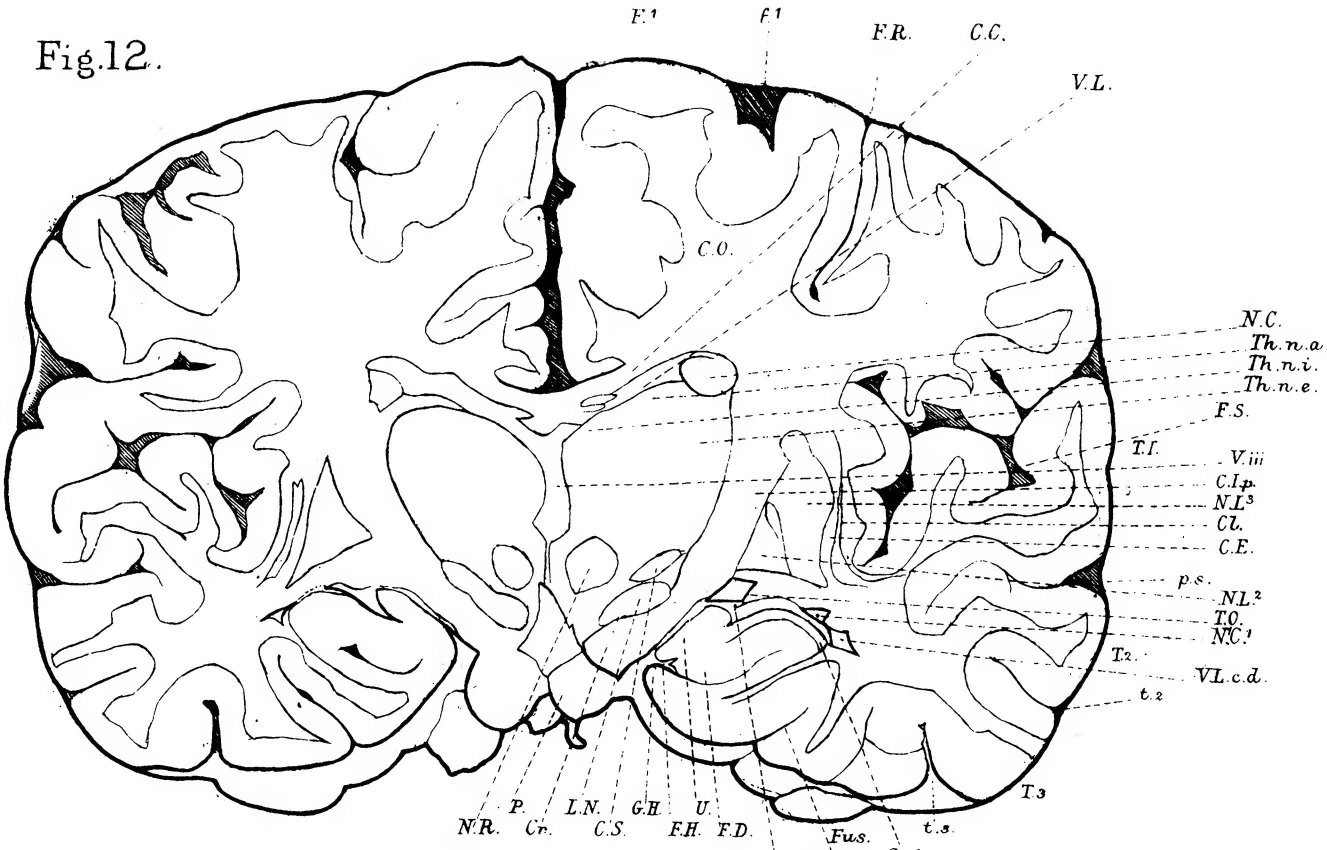
Sg.c.
F.ant.
N.A.

Fig. 10.

Fig. 12.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F.S.
T.I.
V.iii
C.I.p.
N.L.3
Cl.
C.E.
p.s.
N.L.2
T.O.
N.C.1
T.2.
V.L.c.d.
t.2
T.3
t.3.
C.Am
Fus.
P.Ch.l. Coll.
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Cr.
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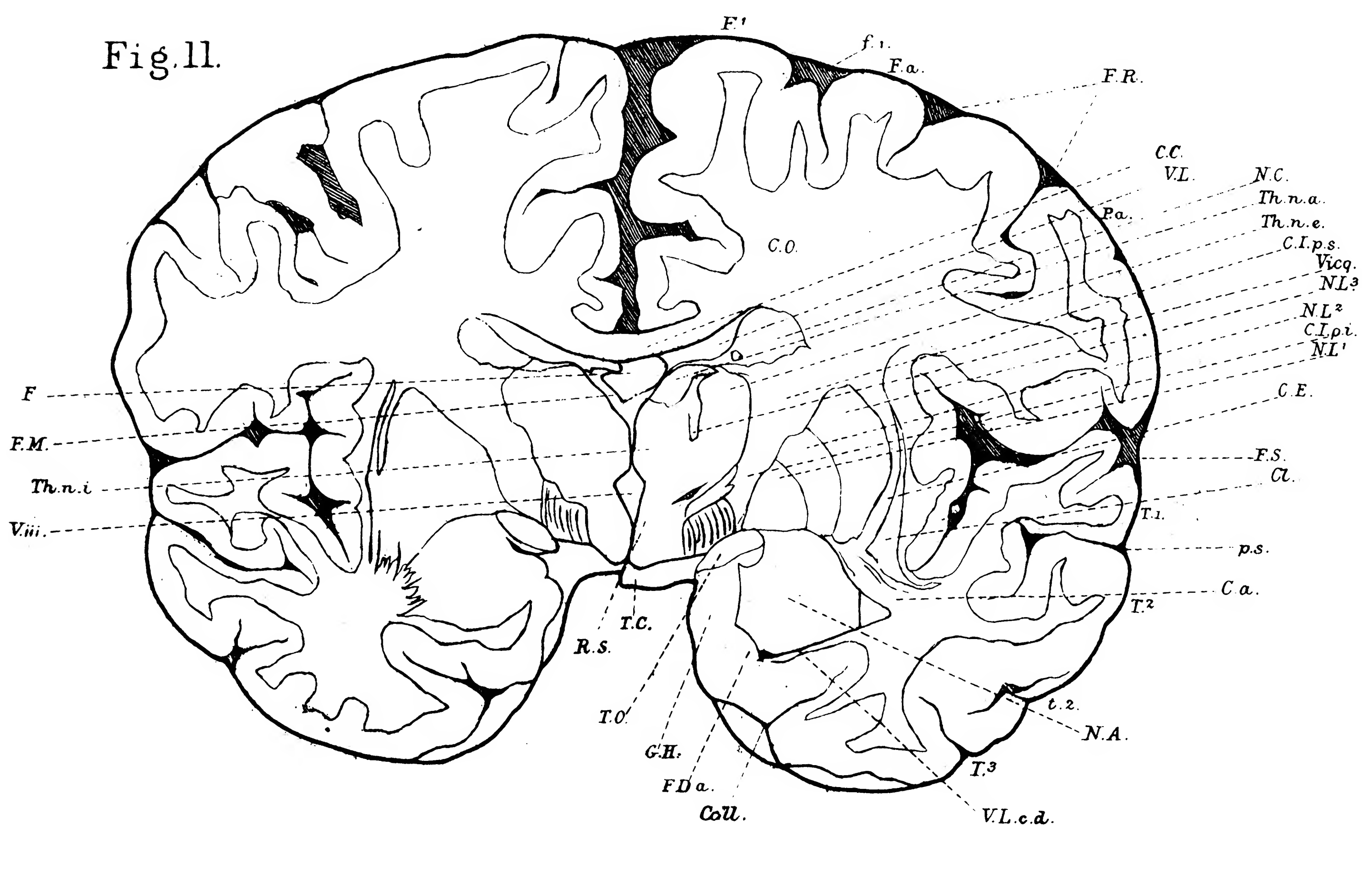
N.R.

Fig. 11.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Vicq.
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N.L.2
C.I.p.i.
N.L.1
C.E.
C.O.
F
F.M.
Th.n.i
V.iii.
F.S.
Cl.
T.1.
p.s.
C.a.
T.2
t.2.
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T.3
V.L.c.d.
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Phil. Trans. B vol. 200, Pl. 6.

Fig. 12.

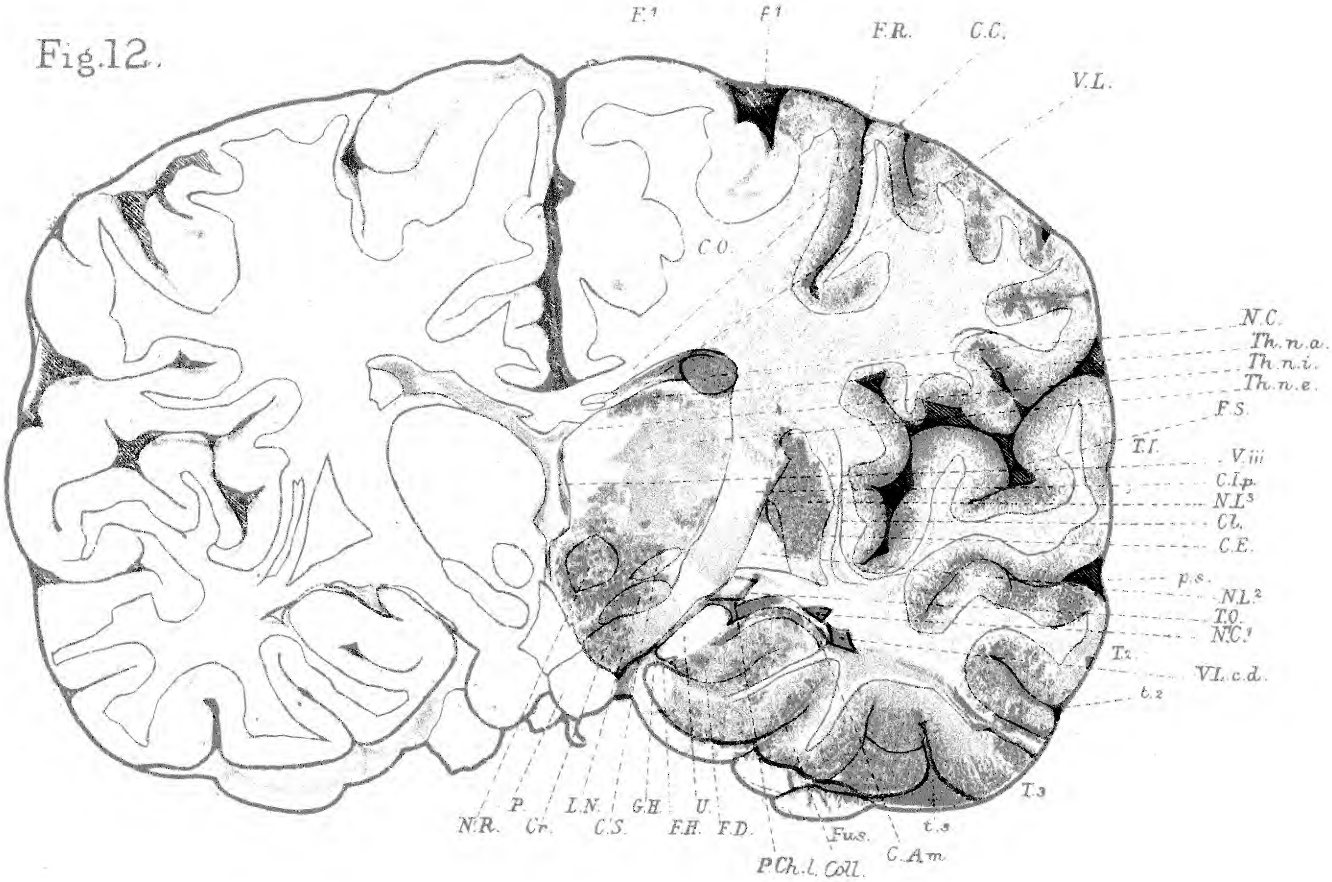


Fig. 11.

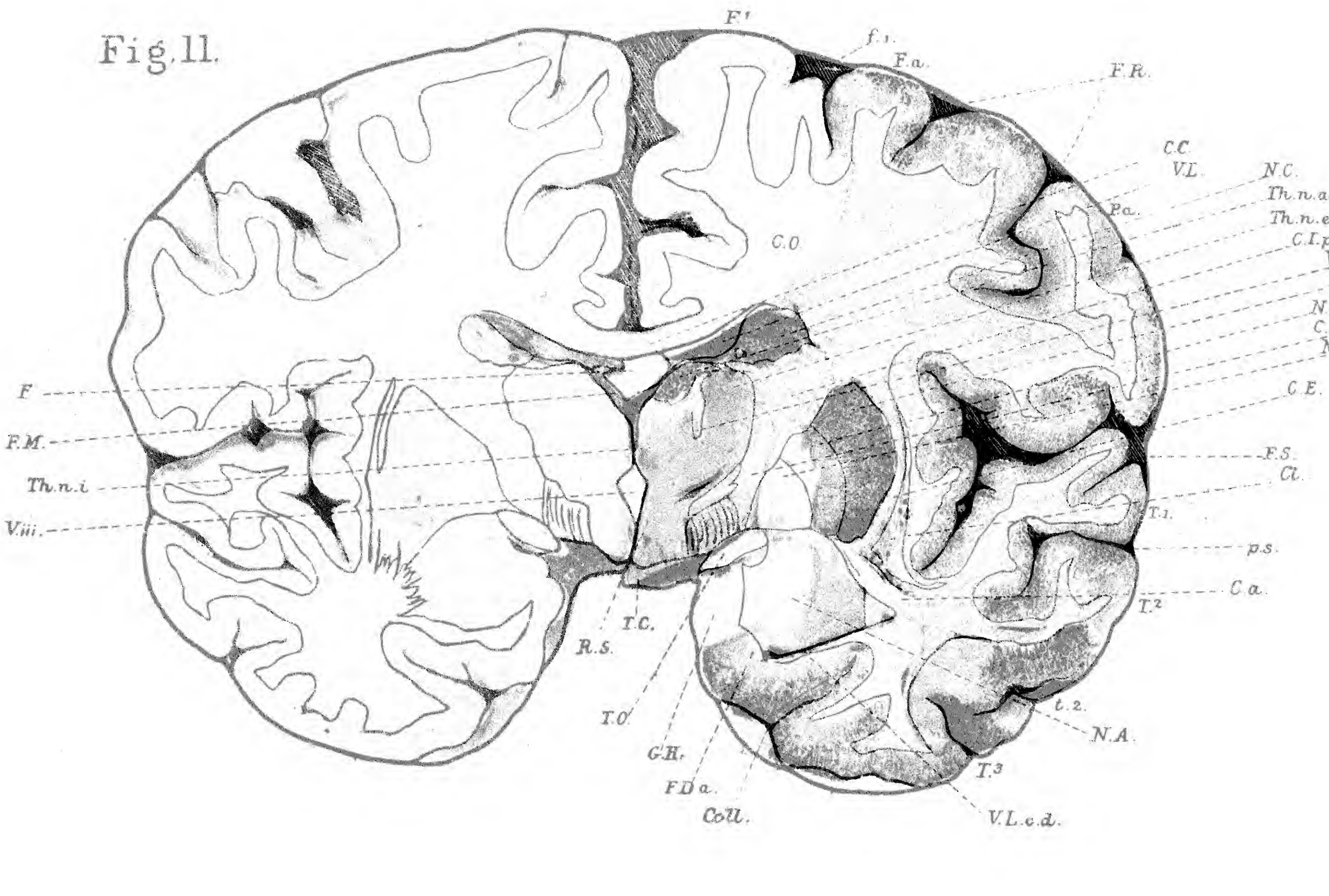
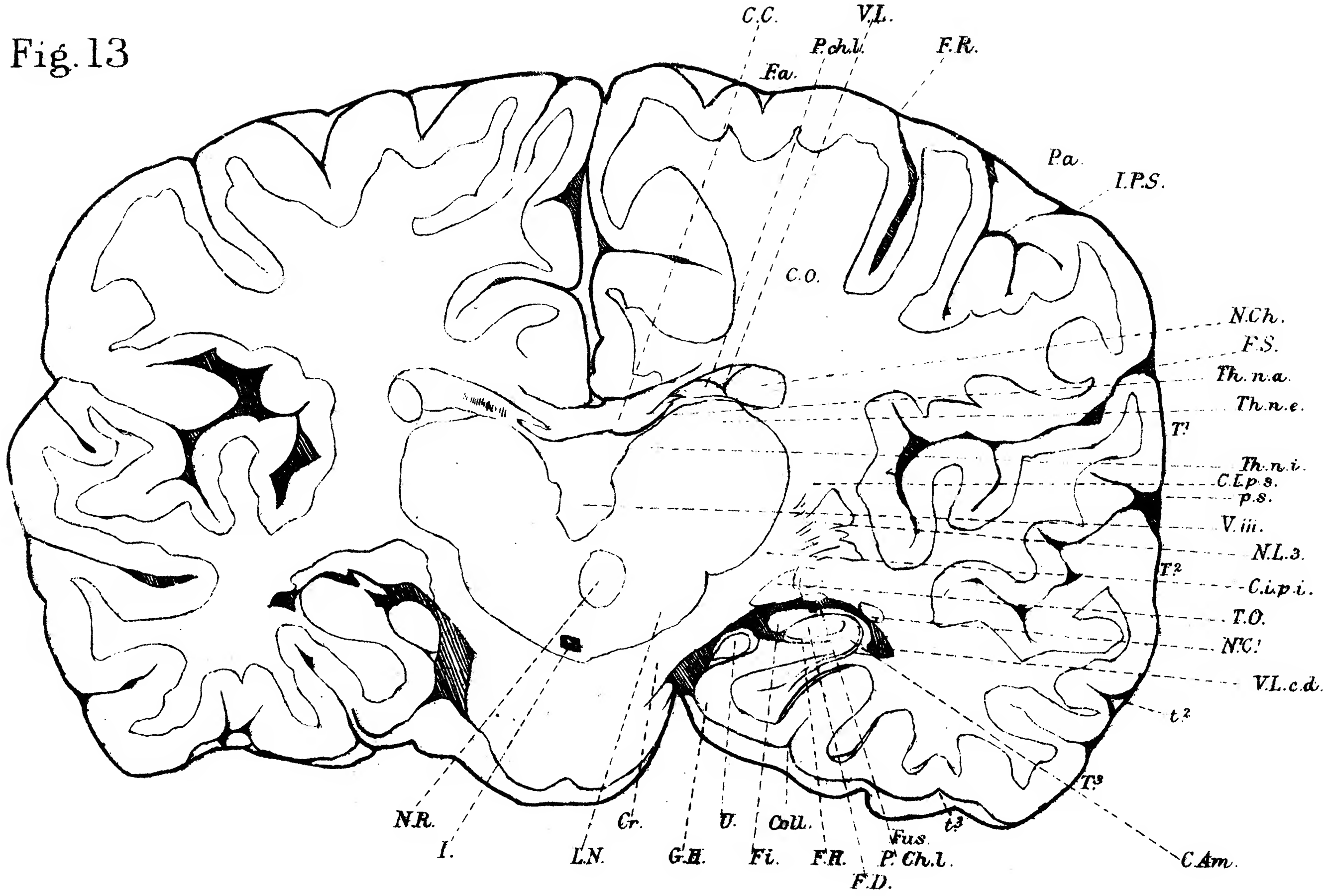


Fig. 13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Th.n.e.
T1
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C.I.p.s.
p.s.
V.iii.
N.L.3.
T2
C.i.p.i.
T.O.
N.C.1
V.L.c.d.
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T3
C.Am.
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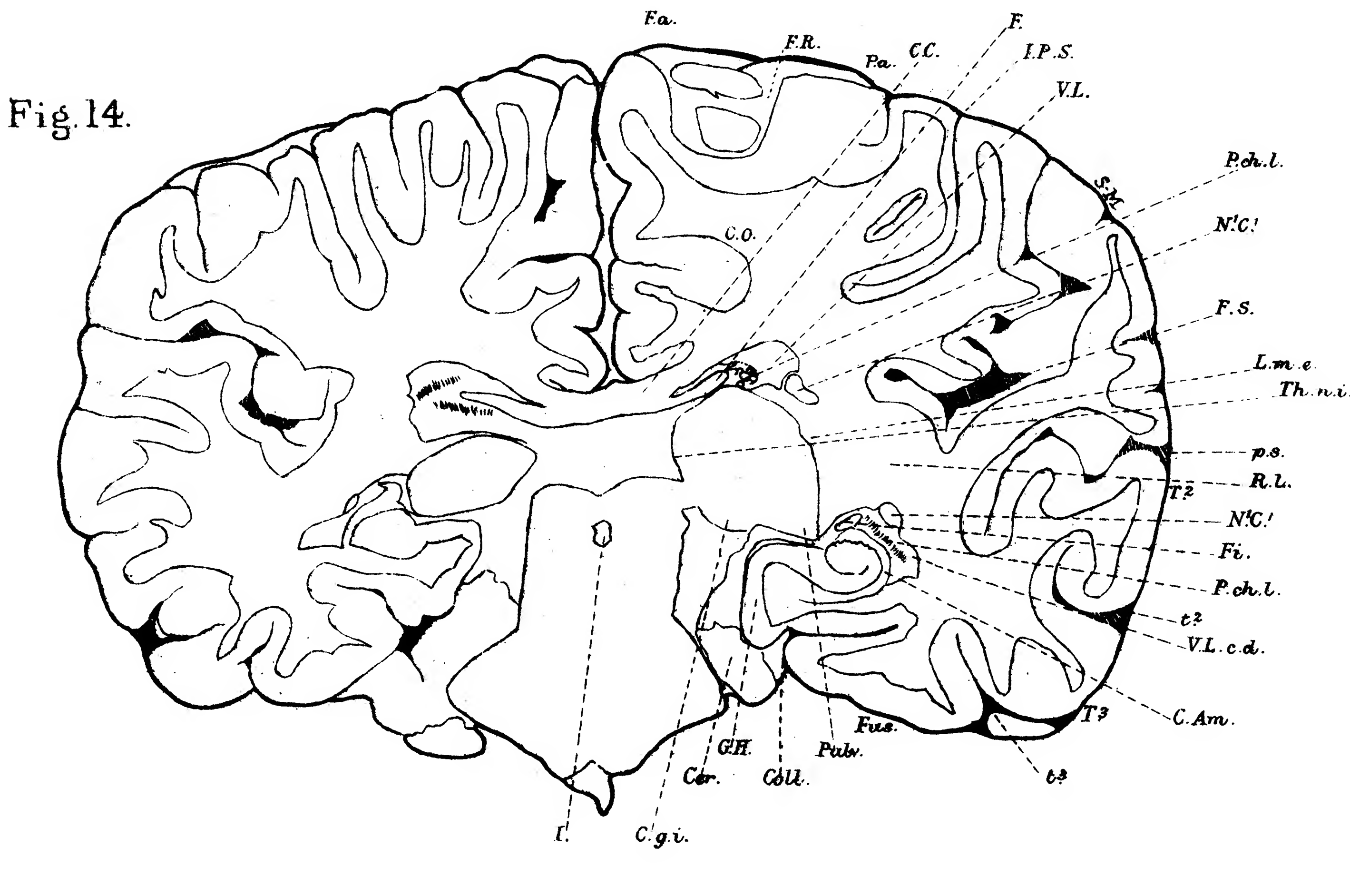
P. Ch.l.
F.D.

Fig. 14.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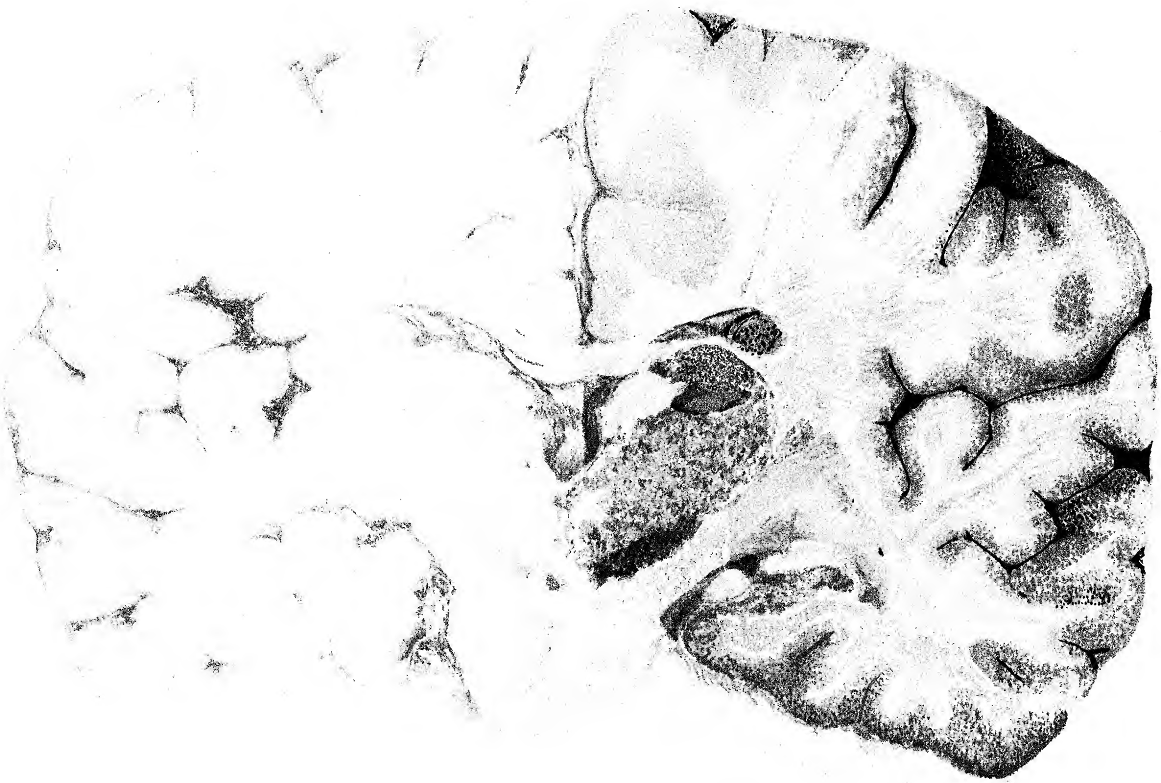
C.g.i.



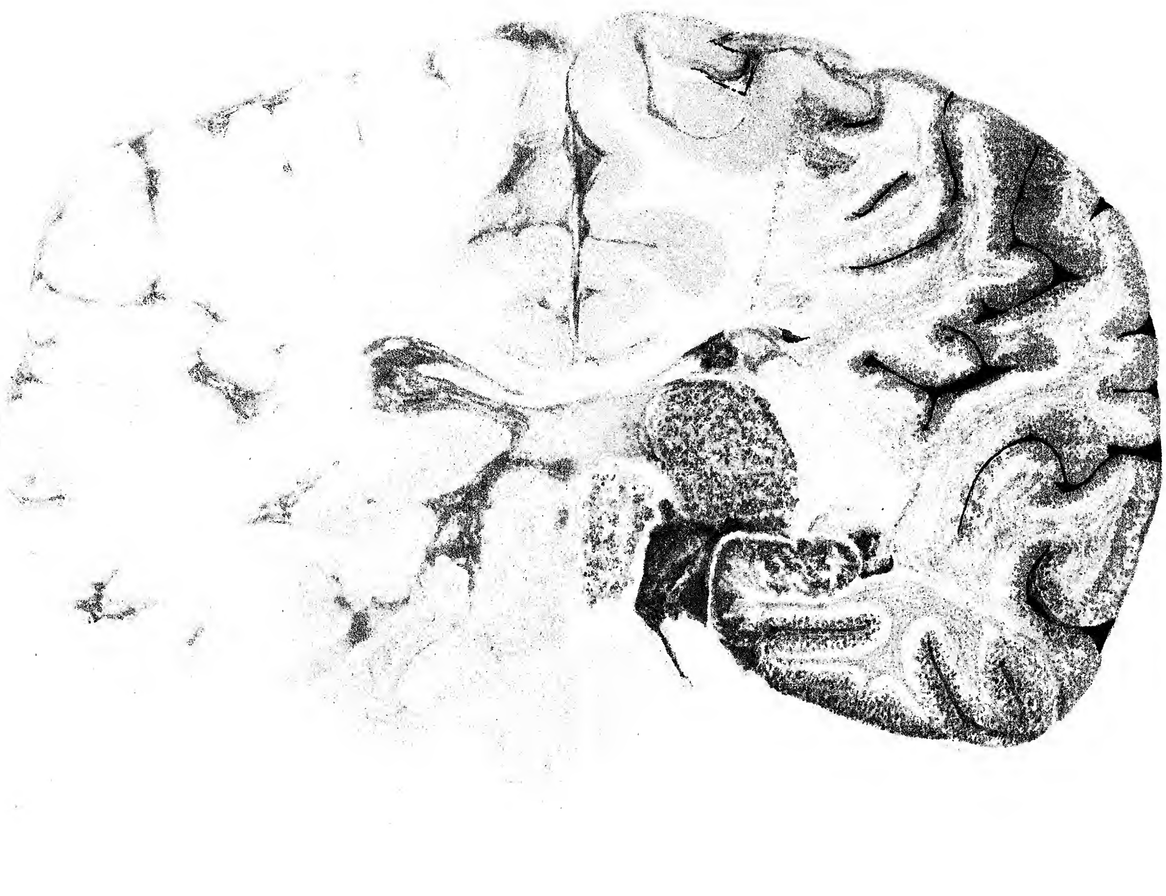
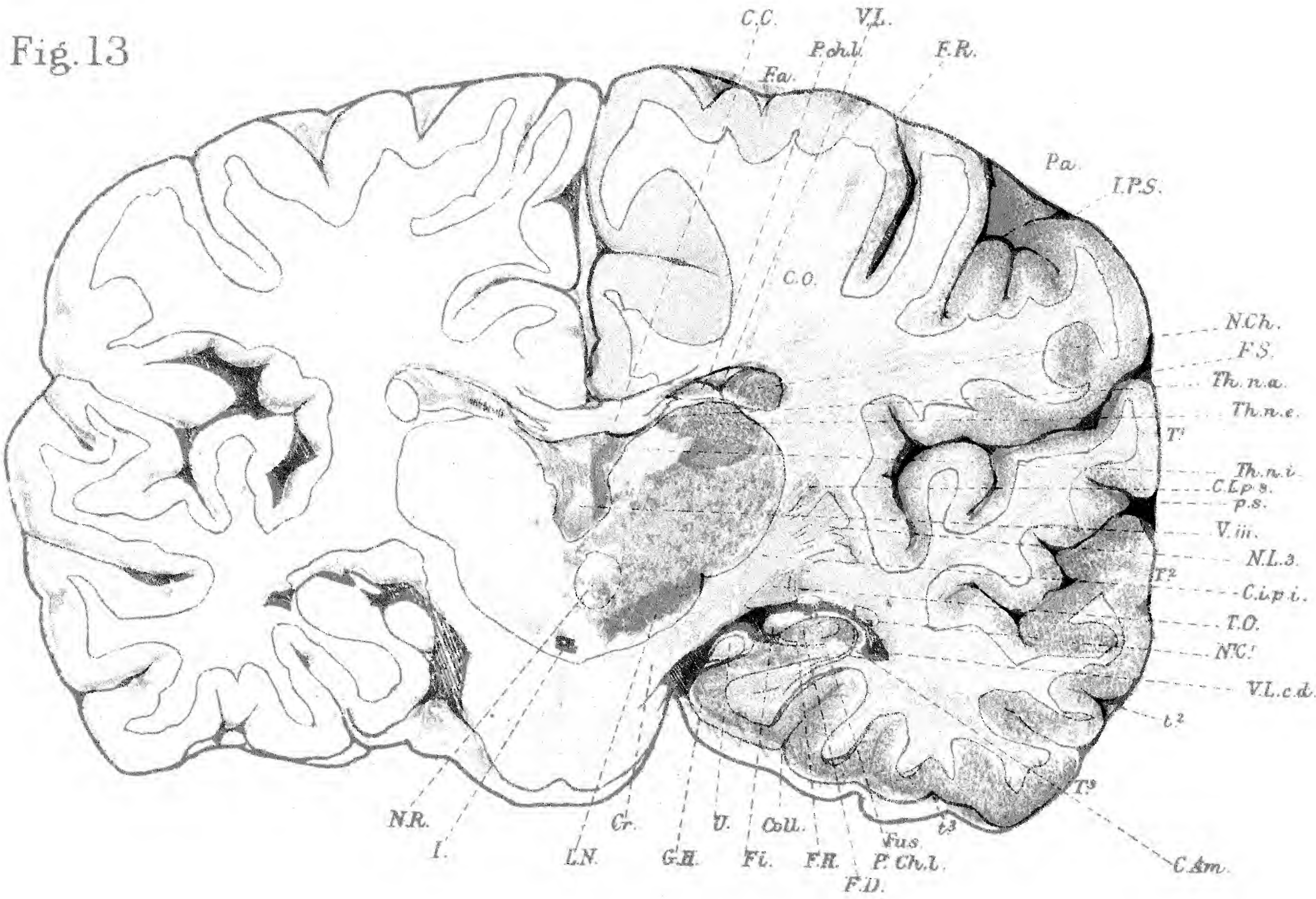


Fig. 13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T¹
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T²
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N¹C¹
V.L.c.d.
t²
T³
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N.R.
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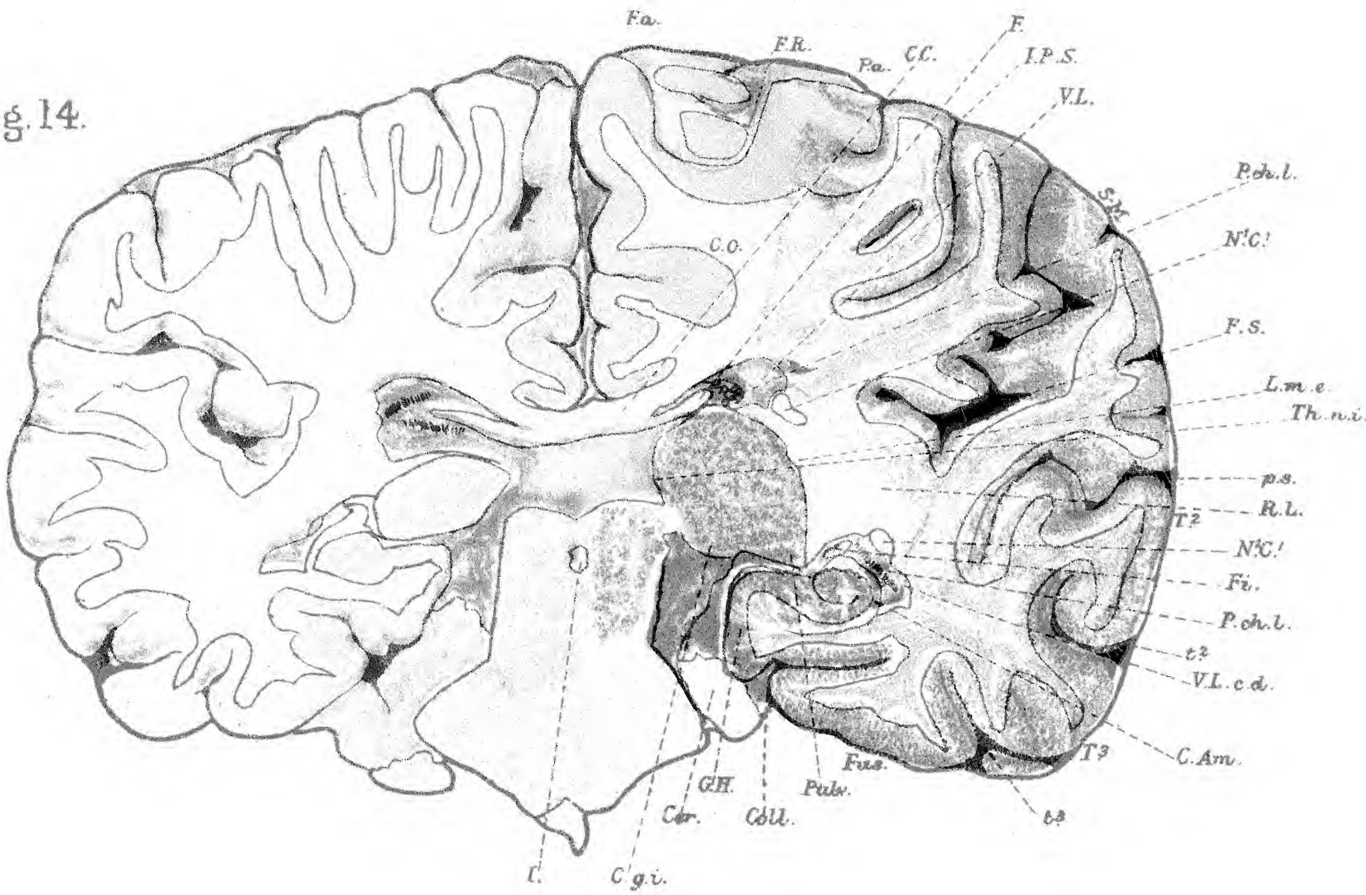
Fig. 14.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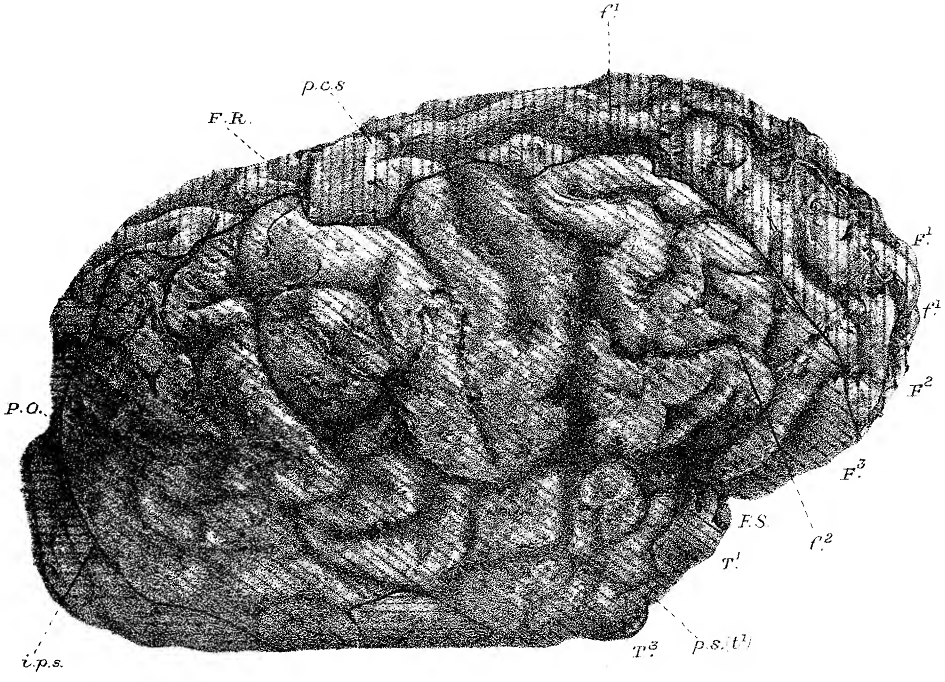


Fig. 15.

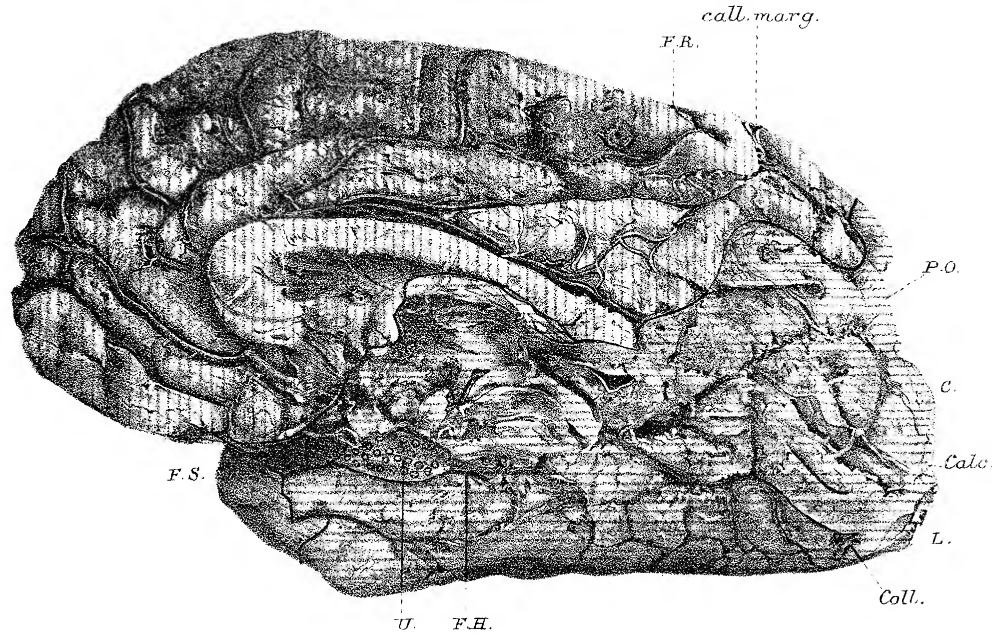


Fig. 16.

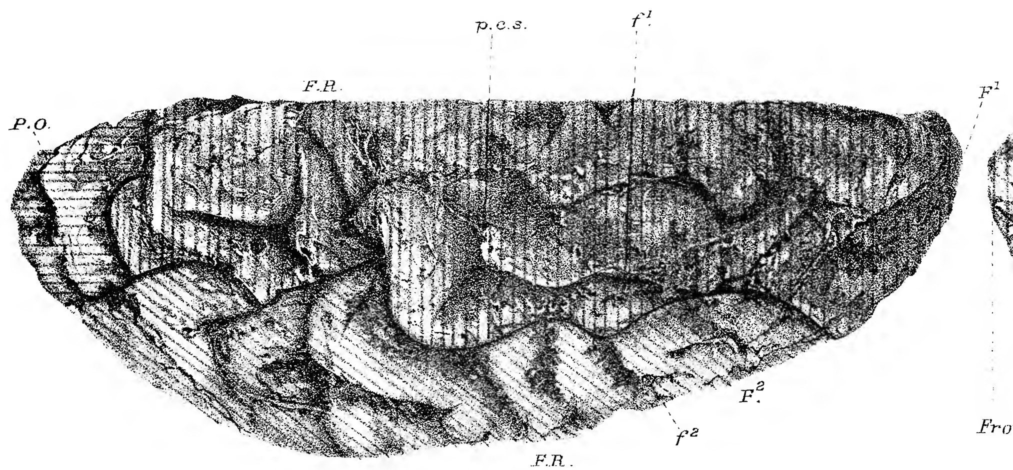


Fig. 17.

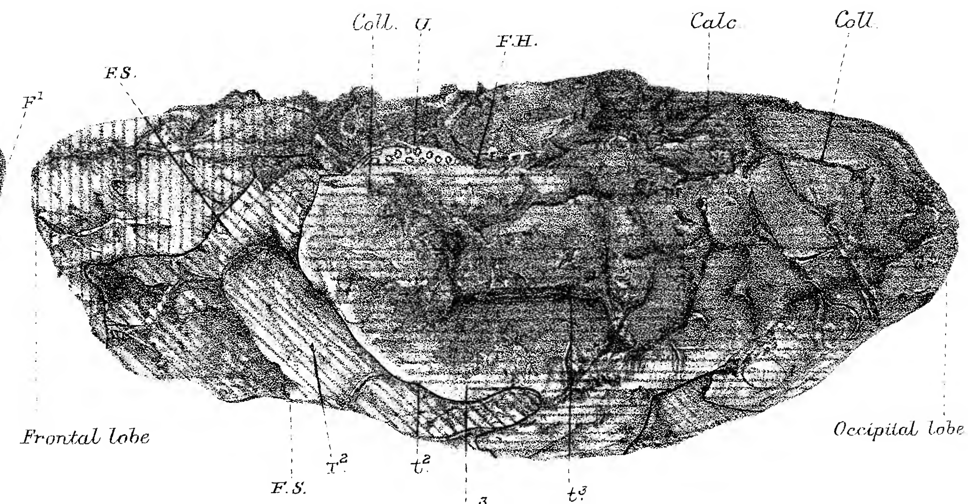
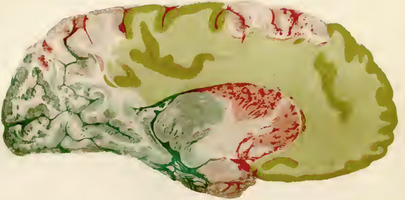
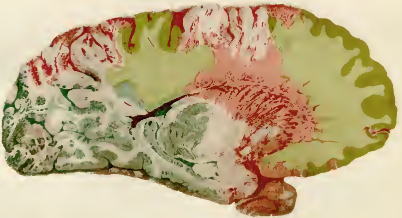


Fig. 18.

Ruth. Lithr London.





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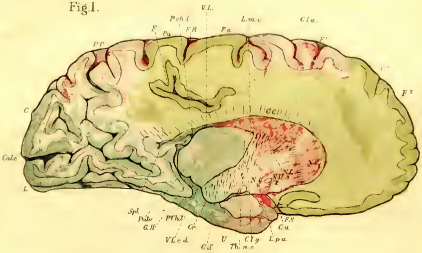


Fig. 2.

PLATE 1.

Figs. 1 and 2.—Sagittal sections of the human brain made $\frac{3}{8}$ inch (1 cm.) and $\frac{9}{16}$ inch (1·5 cm.), respectively from the median surface of the left hemisphere. The three arteries, anterior, middle, and posterior cerebral were injected at the same time, the posterior communicating artery was ligatured at each end, and the anterior choroid artery was ligatured at its origin (Class D, pp. 13, 14), so that the areas supplied by these two arteries are not injected, and appear white.

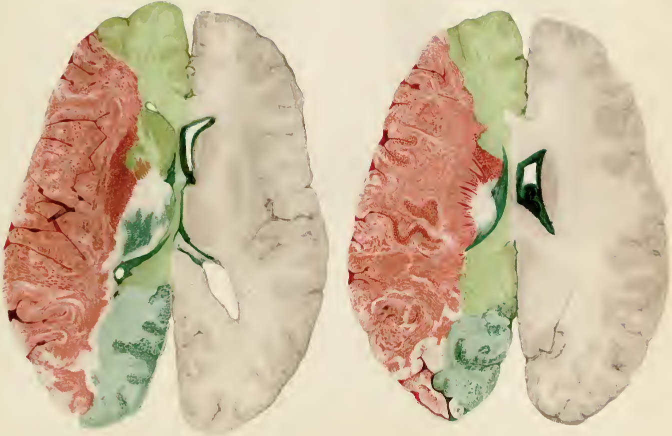


Fig. 4.

Fig. 3.

PLATE 2.

Figs. 3 and 4.—Horizontal sections of the human brain made through the most superior part of the optic thalamus, and of the lenticular nucleus respectively. Four arteries, the anterior, middle, and posterior cerebrals and the anterior choroid were injected simultaneously, and the posterior communicating artery was ligatured at each end (Class E) and the area supplied by it is not injected.

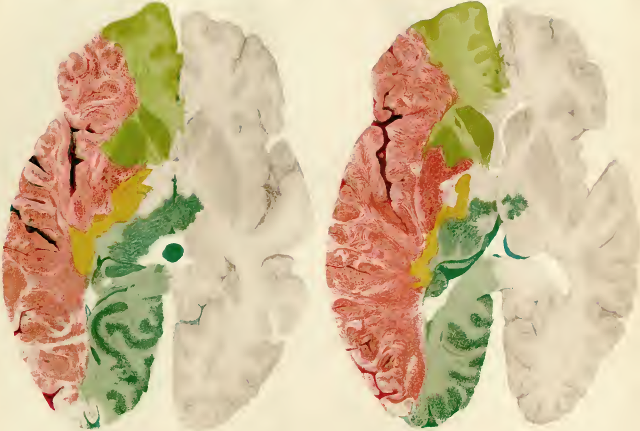


Fig. 6.

Fig. 5.

PLATE 3.

Figs. 5 and 6.—Horizontal sections of the same brain made through the most superior part of the internal segment of the lenticular nucleus, and of the anterior commissure respectively. The arteries are injected as in Plate 2.

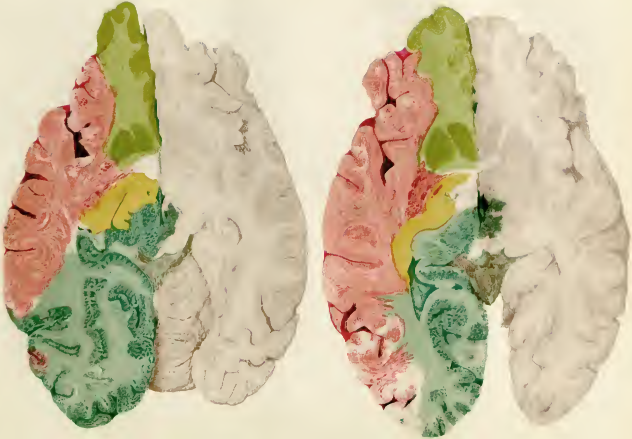


Fig. 8.

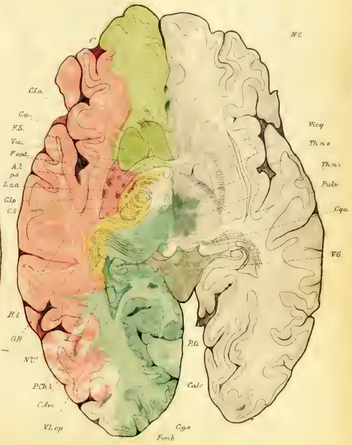
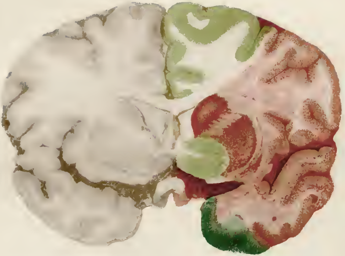


Fig. 7.

PLATE 4.

Figs. 7 and 8.—Horizontal sections of the same brain made through the superior part of the corpora quadrigemina, and the nucleus ruber with the corpora geniculata, respectively. The arteries are injected as in Plate 2.



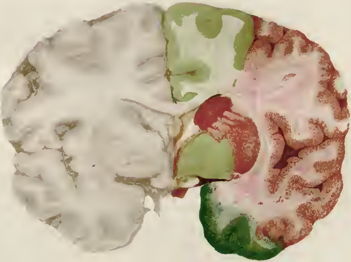


Fig. 9

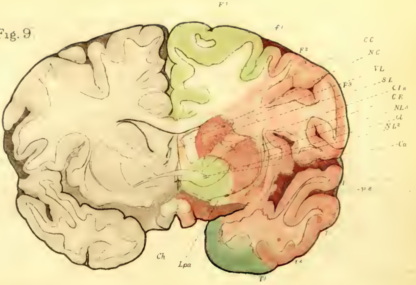
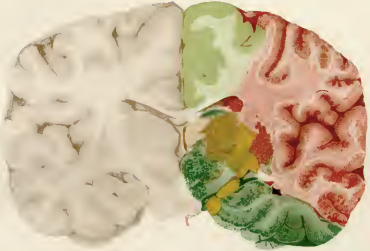


Fig. 10.

PLATE 5.

Figs. 9 and 10.—Coronal sections of the human brain made through the anterior commissure (superior median part), and just posteriorly to the optic chiasma, respectively. Five arteries, the anterior, middle, and posterior cerebrals, the anterior choroid, and the posterior communicating arteries were simultaneously injected with different colours (Class G).



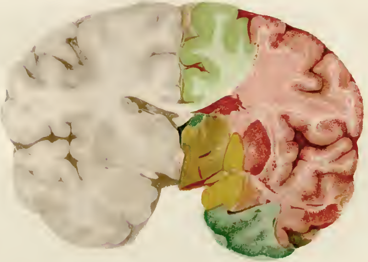


Fig. 12.

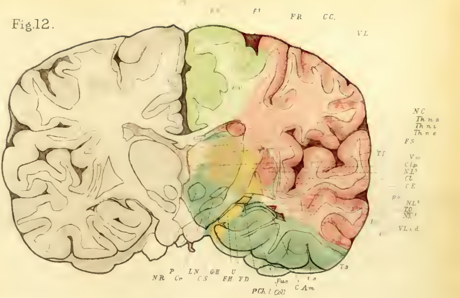
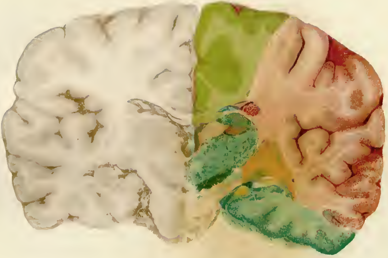


Fig. 11.

PLATE 6.

Figs. 11 and 12.—Coronal sections of the same brain made through the tuber cinereum and the genu of the internal capsule, and through the most anterior part of the pons, respectively. The arteries are injected as in Plate 5.



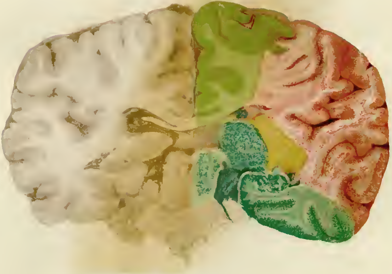


Fig. 13.

Fig. 14.

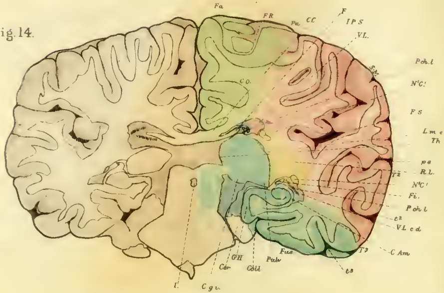


Plate 7.

Figs. 13 and 14.—Coronal sections of the same brain made just posteriorly to the lenticular nucleus, and through the posterior part of the optic thalamus, respectively. The arteries are injected as in Plate 5.

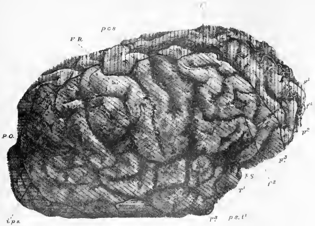


Fig.15.

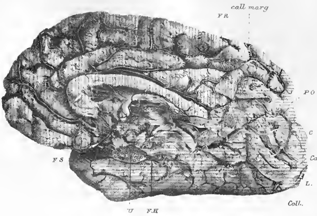


Fig.16

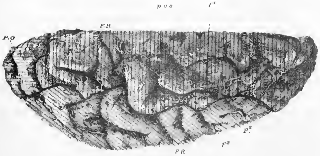


Fig.17.

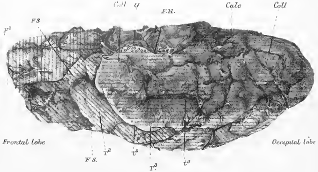


Fig.18.

PLATE 8.

Figs. 15 and 16 show the external and median surfaces of a brain in which the anterior, middle, and posterior cerebral arteries were separately injected.

Figs. 17 and 18 show the superior and inferior surfaces of the same brain. In figs. 15 and 17, the posterior cerebral area extends beyond the external parieto-occipital fissure for half way along the parietal lobule, so as to join the anterior cerebral area and so prevent the middle cerebral area from reaching the median line, as commonly occurs (see fig. 5, p. 33).

N.B.—The small ringed areas in figs. 16 and 18 were filled in from another brain where the anterior choroid artery was also injected.